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PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

(FOUNDED 1858.)

VOLUME THE NINETEENTH,

1905-1906.

EDITED BY

A. E. SALTER, D.Sc., F.G.S.

(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

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Page 7, line 6, *for* " Plaxtol " *read* " Plaxdale."
„ 7, line 15, *for* " North of Greenhithe " *read* " South of Greenhithe."
„ 7, line 23, *for* " Mr. F. G. Spurrell " *read* " Mr. Flaxman C. J. Spurrell."
„ 158, List of fossils ; second column.
„ „ *for* " *Serpula cincta*. Goldf. (c) " *read* " *Serpula cincta* (?) Goldf."
„ „ *for* " *Serpula*, sp. (?) " *read* " *Serpula* sp."
„ „ *for* " *Echinocorys scutatus*, Leske " *read* " *Echinocorys scutatus*, Leske (v.c.)."
„ „ *for* " *Infulaster excentricus*, Rose (v.c.) " *read* " *Cardiaster Cotteauanus*, d'Orb."
„ 312, line 13, *for* " some pectens " *read* " some limas and pectens."
„ 313, line 11, *for* " *Leiodon* " *read* " *Coniasaurus crassidens*," Dixon.
„ 314, line 37, *for* " Howarth " *read* " Howorth."
„ 346, *Diagram*. *All* beds from *a* to *g* should be classed as " Woolwich Beds."
„ 361, line 29, Insert full stop (.) after " *Gervillia*."
„ „ line 30, *for* " *Apporhais* " *read* " *Aporrhais*."
„ 375, *Footnote*. *For* " east " *read* " west."
„ 376, line 35, *for* " Howarth " read " Howorth."
„ 457, Delete the ° (degrees) in analysis, except in first line (of that part).

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

ON THE SUPERFICIAL DEPOSITS OF CENTRAL AND PARTS OF SOUTHERN ENGLAND.

By A. E. SALTER, D.Sc. (London), F.G.S.

(Read December 2nd, 1904.)

INTRODUCTION.

THERE is probably no branch of British Geology which has excited more controversy, or has more special literature devoted to it, than that dealing with the superficial deposits. Their production has been attributed to diluvial, marine, or ice agency by various writers, and opinion on them is, even now, by no means settled. This must be my excuse for attempting to treat the subject in a manner which, in the area studied, has not been thoroughly worked out before.

After some preliminary remarks on the denudation and drainage of calcareous strata dipping at a gentle angle, the various superficial deposits of the Lower Thames-Kennet basin and portions of East Anglia within the Chalk escarpment are considered. Then those of the area between the Cretaceous and Jurassic escarpments in Central England are taken, and their relation to those within the escarpment noted, followed by a description of similar deposits outside the above-named areas.

PRELIMINARY REMARKS ON THE DENUDATION OF INCLINED SLOPES OF CALCAREOUS STRATA.

The area under consideration consists largely of inclined Cretaceous and Jurassic strata which have undergone considerable physiographical modification by subaerial weathering, fluviatile erosion, and possibly other agencies.

Recently the various phenomena connected with river development have received much attention in England, America, and the continent of Europe, as the writings of Lord Avebury,[*] Professors W. M. Davis,[†] I. Russell,[‡] J. E. Marr,[§] and others[||] testify, and it is not here intended to recapitulate their results, but rather to draw attention to one important aspect of the subject not fully entered upon by them. I refer to the evidence afforded by the *constituents* of the superficial deposits themselves, which result from the action of the various denuding agents upon sloping strata, especially those occurring over wide areas.

The presence of a great thickness of calcareous strata in Central and Southern England has had an immense influence in bringing about the present surface features in that area, and I propose to take a hypothetical case involving this feature in order to explain the various phenomena observed.

Imagine a series of inclined calcareous beds with superincumbent, intercalated and subjacent argillaceous, or arenaceous deposits, resting on older rocks unconformably, exposed to subaerial agencies.

The following points about such a slope may be noted:

1. Its formation, whether belonging to one period of time, whether continued through a long period, or whether successive stages may have taken place. Any of these would, in all probability, leave its mark on the denudation effects of the area concerned.

2. The effects of denudation upon it. These will be found as the result of:

(*a*) *Subaerial weathering*, acting generally over the entire area and leaving characteristic deposits as evidence of its action. These will depend on the character of the rock, especially as regards the quantity of insoluble matter it contains. They may occur at all heights where they have been left undisturbed by subsequent fluviatile action. The clay with flints on the chalk downs, is a case in point.

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[*] Lord Avebury, "The scenery of England and the causes to which it is due."

[†] *Cf.* Prof. W. M. Davis, "The development of certain English rivers," *The Geographical Journal* for 1895, vol. v, p. 127. "The Drainage of Cuestas," *Proc. Geol. Assoc.*, vol. xv, p. 75.

[‡] "River Development," Progressive Science Series, J. Murray.

[§] J. E. Marr, "The Scientific Study of Scenery."

[||] S. V. Wood, Jun., "The Newer Pliocene Period in England," *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 457, and vol. xxxviii, p. 667. Prof. A. C. Ramsay, "On the River Courses of England and Wales," *Quart. Journ. Geol. Soc.*, vol. xxviii, p. 148. W. Whitaker, "On subaerial denudation." *Geol. Mag.*, 1867, p. 447. Sir J. Prestwich, "Memoranda chiefly on the Drift deposits of various parts of England and Wales," *Geol. Mag.*, Dec. 4, vol. 5, p. 404. Sir H. Howarth, "The evidence of the rolled gravel and sands," *Geol. Mag.*, 1883, p. 413. J. Geikie, "Earth Sculpture, or the origin of land forms," Progressive Science Series, *cf.* pp. 65-68. H. Carvel Lewis, "The Glacial Geology of England and Wales," Prof. W. W. Watts, Address to Section C British Association, 1903. *Cf.* Nature, vol. 68, p. 485.

(*b*) *Fluviatile denudation.* Owing to river capture a few of the initial (consequent) streams, which have some natural advantage, will increase in size, erode their beds and gradually expose older rocks. The resulting débris will be carried down the slope and deposited chiefly on the lower ground at the base. As denudation proceeds this, in some cases, will be left and serve as a record of the history of the stream at the time of its deposition, for, being usually of a pervious character, it acts as a protective agent to the strata below. It thus happens that such deposits are often eventually found capping hills in the neighbourhood of the stream to which they owe their existence and offer most important evidence as regards the original extent of the surface, etc.

The deposits laid down by the smaller streams descending the slope will usually be of a much simpler and more local character, as they will not cut their beds so deeply. They also drain a smaller area as a rule.

(*c*) Owing, among other things, to the calcareous nature of the beds, escarpments have been produced, which have been gradually cut back and so lessened the area of the basins of many of the dip streams and have brought into existence a series of longitudinal and anti-dip (obsequent) streams, which have usually found their way into the stronger dip-streams, over the surface of the older rocks thus exposed.

The rate at which this will take place will depend on :

1. The thickness and character of the calcareous strata forming the escarpment.
2. Whether these are covered by beds of a protective character, and
3. The severity of the climatic conditions.

These changes give rise to alterations in the character of the deposits laid down by the main streams, which in course of time form gaps or gorges in the strata concerned. It is in or near these gaps that various deposits are found, and a series differing slightly in height will usually be present, the highest of which will be the oldest unless some disturbing element has been introduced. Sharp differences in the character of such deposits would not be expected, but they would rather shade off one into the other. To such deposits the term "Drift Series" might be applied, and the evidence derived from them used to interpret the former history of the drainage area which supplied them.

When it is considered what great changes in topography can be brought about by removal of large tracts of soluble strata, the value of such evidence is considerable, and extremely useful in testing the numerous hypotheses with regard to the former extension of the Thames and other river basins recently advanced on what may be looked upon as rather meagre evidence.

PART I.

THE SUPERFICIAL DEPOSITS FOUND ON THE SOUTH SIDE OF THE BASIN OF THE LOWER THAMES.

These are taken first because of their simple character, no strata older than the Purbeck being exposed in the Wealden area to the south. These deposits have been well studied by Sir J. Prestwich,[*] W. Topley,[†] F. G. Spurrell,[‡] and others,[§] and there is more agreement as to their mode of origin than is the case with similar deposits found north of the Thames. They are also most useful for illustrating the value of the "working hypothesis" referred to in the Introduction, before dealing with more complicated areas.

A. Area North of the Chalk Escarpment.

1. *The country east of the Kentish Stour.*—The highest points of the Chalk range of this area are capped by a subaerial deposit of clay containing unrolled flints and blocks of ironstone. Well defined deposits at lower levels are rare.

Details:

(*a*) On the tops of the hills between Folkestone and Dover, 547 ft. O.D., pipes containing dark brown clay with flints and ironstone occur. As I was unable to detect any fossils in the ironstone I am not in a position to state if it is of Pliocene or Wealden Age. Similar deposits occur at Paddlesworth, 609 ft. O.D.

(*b*) About two miles north of Westenhanger Station, 600 ft. O.D., the same kind of deposit occurs again, but the ironstone contains casts of Pliocene fossils similar to those found at Lenham, farther west.

(*c*) At Shepherd's Well,[||] about seven miles from Dover, and 420 ft. O.D., a Pleistocene deposit, with Elephas primigenius, Rhinoceros tichorhinis occurs.

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[*] Sir J. Prestwich, "On the relation of the Westleton Shingle to the other Pre-Glacial Drifts in the Thames Basin and on a Southern Drift," etc., *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 155.

[†] *Cf.* W. Topley, *The Weald*, p. 270.

[‡] F. C. G. Spurrell, "A Sketch of the History of the Rivers and Denudation of West Kent." Pamphlet published in 1886.

[§] S. V. Wood, Jun., in "Newer Pliocene," *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 690, is of a different opinion.

[||] *Cf. English Mechanic*, 1900, p. 142.

(*d*) A more recent (Holocene) deposit at Buckland, near Dover, has been described by the Rev. R. A. Bullen, F.G.S.[*]

A. 2. The Stour Gap.

In and around the mouth of this gap a better "Drift Series" is found. The level of the river is between 40 ft. and 70 ft. O.D., and deposits at various heights are found consisting at the higher levels chiefly of flint débris and a little ironstone (Pliocene). At lower levels débris from the strata below the Chalk occurs. This is accounted for by the low elevation of the Wealden dome to the south.

Details:

(*a*) On Charing Hill, 627 ft. O.D., a subaerial deposit containing large flints, Pliocene ironstone, Tertiary flint pebbles, and sarsens occurs.

(*b*) Capping the hills west of Canterbury on which stand Dunstead, Thornton and Blean Woods, and from 250 ft. to 317 ft. O.D., is a deposit consisting of débris from the Chalk and Tertiary formations only.

(*c*) At Kennington and Willesboro', 208 ft. O.D., the superficial deposits contain pebbles of Wealden Sandstone in addition to the materials found in the higher deposits.[†]

(*d*) At Canterbury Mr. W. G. Smith[‡] has obtained Palæolithic implements from the gravels at 80 ft. and 100 ft. above the River Stour, and also in similar gravel near Reculver at 100 ft. O.D.

A. 3. The Country Between the Stour and Medway Gaps.

The superficial deposits in this area are not extensive, owing to its position between two gaps. The occurrence, however, of much Pliocene Ironstone with numerous casts of Lower Pliocene fossils at Lenham furnish important evidence for estimating, within definite limits, the probable age of other and more recent deposits.

Details:

(*a*) At Lenham, 626 ft. O.D., brown clay with flints and Pliocene Ironstone occurs.[§] This latter occurs as blocks

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[*] Rev. R. A. Bullen, "Note on non-marine mollusca obtained from Holocene and Pleistocene deposits at Buckland, Dover." *Proc. Malacological Soc.*, vol. iii, p. 162.

[†] *Cf.* "Weald Memoir of the Geological Survey," and S. V. Wood, Jun., "On the evidence afforded by the detrital beds within and without the N.E. part of the valley of the Weald," *Quart. Journ. Geol. Soc.*, vol. xxvii, p. 3.

[‡] *Cf.* "Nature," vol. xxiv, p. 29.

[§] *Cf.* C. Reid, "Excursion to Lenham," *Proc. Geol. Assoc.*, vol. xii, p. 385. Sir J. Prestwich, "On the sands and iron sandstones of the North Downs," *Quart. Journ. Geol. Soc.*, vol. xiv, p. 321. F. Harmer, "The Pliocene Deposits of the East of England, The Lenham Beds," etc., *Quart. Journ. Geol. Soc.*, vol. liv, p. 308.

in the clay and not *in situ*, pointing to much denudation and the occurrence of earth-movements during or since Pliocene times.

(*b*) At Broughton, near Faversham, 194 ft. O.D., is a deposit 5 ft. thick, consisting of Tertiary flint pebbles, subangular flints in all probability derived from older drifts to the south.

(*c*) Remains of *Elephas primigenius* have been obtained from the lower ground at Sittingbourne.*

A. 4. The Medway Gap.

This gap has been cut down almost to sea-level. The Medway by its closer proximity to the sea and other natural advantages has been able to extend its valley within the Chalk Escarpment, and by thus obtaining a greater volume of water has excavated its valley to a great extent and depth.

Details:

(*a*) The deposits formed by subaerial weathering do not call for special attention.

(*b*) At Cobham Park, 400 ft. O.D., and extending towards the Medway, is a deposit included by Sir J. Prestwich in his "Southern Drift." It is made up of flint pebbles and pieces of subangular flint together with pieces of Lower Greensand Chert. The distribution of this latter material is of special importance as it is derived from strata lying within the chalk escarpment, but now separated from it by a broad, deep valley. The extent of country over which it is found is remarkable, and its plentiful occurrence on the north side of the Thames Basin will be considered later.

(*c*) The highest point of the Isle of Sheppey, 209 ft. O.D., is capped by gravel† derived from the south and probably through this gap.

(*d*) On Stroud Hill, 200 ft. O.D., much Wealden Sandstone is present.

(*e*) Many large sarsen blocks occur in and near this gap, *e.g.*, Kit's Coity House, about 250 ft. O.D., near Aylesford, etc.

(*f*) Near Aylesford, below 50 ft. O.D., are 20 ft. of superficial deposits, containing ironstone, Oldbury stone, chert, blocks of Kentish rag, sarsens, etc. Rhinoceros, *Elephas primigenius*, and *Elephas antiquus*, according to Professor Boyd Dawkins, occur here.‡

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* *Cf.* H. A. Allen, "Summary of Progress for 1903," p. 62.

† *Cf.* Sir J. Prestwich, *Quart. Journ. Geol. Soc.*, vol. x, p. 404.

‡ *Cf.* "Excursion to Cuxton, etc.," F. J. Bennett, F.G.S., *Proc. Geol. Assoc.*, vol. xviii, p. 463.

A. 5. The Country Between the Medway and Darent Gaps.

In this area, on the high ground, about 500 ft. O.D., much débris from the Lower Greensand is found in the superficial deposits. Mr. B. Harrison informs me that débris from the Gault also occurs sparingly.

Details:

(*a*) Above 500 ft. O.D., at Ash, Fairseat, Plaxtol Green, Wrotham Hill, etc., chert and ragstone from the Lower Greensand are plentiful.[*]

(*b*) Swanscombe Hill,[†] 316 ft. O.D., is capped by a thin deposit containing similar material. It is now separated from the main mass of the dip slope by subsequent denudation.

(*c*) At Bean, north of Greenhithe, 200 ft. O.D., deposits of gravel derived from (*a*) and (*b*), together with brick-earth and sand, occur.

(*d*) Near Gad's Hill, 272 ft. O.D., several sarsens occur.

Several important deposits below 100 ft., connected with the present Thames, will be considered later.

A. 6. The Darenth Gap.[‡]

Unlike the other gaps, this cuts through the Chalk only. Mr. F. G. Spurrell,[§] however, is of opinion that the Lower Greensand was formerly pierced by this river at Plaxtol, 450 ft. O.D., where, what he considers to be gravels of the old stream, are found.

In comparing the heights of the deposits of this valley, it must be remembered that the bed of the Darenth at the gap is about 200 ft. O.D.

Details:

(*a*) Subaerial deposits occur in the hills on either side of the valley. They were well shown about three years ago when the foundations for the new fort at Poll Hill, 700 ft. O.D., were excavated. They consisted of débris of the Woolwich and Reading Beds, and clay, with flints. Similar deposits occur at Knockholt Beeches, 700 ft. O.D.

(*b*) At Well Hill, near Chelsfield, 600 ft. O.D., capping an outlier of the Tertiary Beds, is a deposit 6 ft. to 12 ft. thick, consisting of Tertiary flint pebbles, subangular flints,

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[*] *Cf.* W. J. L. Abbot, "Excursion to the Kentish Plateau," *Proc. Geol. Assoc.*, vol. xiv, p. 196.

[†] *Cf.* "Excursion to Swanscombe," *Proc. Geol. Assoc.*, vol. xiv, 395.

[‡] *Cf.* Sir J. Prestwich, "On the Age, Formation, and Successive Drift Stages of the Valley of the Darent," *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 126.

[§] *Op. cit.*

quartz pebbles, similar to those found in the Wealden Sandstones to the south. Lower Greensand Chert is rare, and much of the flint is weathered, owing to long exposure to solvent and disintegrating agencies. A few of the peculiar ovate quartzites from the Blackheath Beds also occur. Sir J. Prestwich correlated this deposit with the Red Crag, and from my own observations in East Anglia, I am disposed to think this may be correct.

(*c*) Close to the "Fox and Hounds" Inn, about 1½ miles east of Shoreham (Kent) Station, are boulders of flint conglomerate and sarsens at 600 ft. O.D., or 400 ft. above the Darenth at Otford.

(*d*) Old Darenth deposits occur at Lullingstone Park, 366 ft. O.D., and Colegate Farm.

(*e*) At Dartford Heath, 150 ft. O.D., near the junction of the Darenth with the Thames, much gravel, etc., occurs, containing Southern material. This will be again considered later.

(*f*) *Elephas primigenius* has been found at Shoreham in low-lying gravels, and many flint implements near Ightham.*

A. 7. The Country Between the Darenth and Mole Gaps.

The North Downs in this area rise to over 800 ft. O.D., and subaerial deposits are found over extensive areas. At Down,† 500 ft. O.D., they were studied by the late Charles Darwin. The Cray and the Ravensbourne drain the eastern portion of the area, and the Wandle the western. This last formerly extended farther to the south, as shown by the deep, dry gap, with associated gravels in the chalk escarpment north of Merstham.

Details :

(*a*) Capping Shooter's Hill, 424 ft. O.D., which is separated by denudation from the main mass to the south, is a thick deposit, consisting chiefly of the débris of Tertiary beds, but Quartz pebbles, etc., from the south occur sparingly. Its position away from the Gaps would account for this paucity.

(*b*) The high ground between the Ravensbourne and the Wandle has a thin covering of gravel in places. Sir J. Prestwich describes a section at West Ho, near Norwood, 360 ft. O.D. and 8½ ft. thick, the constituents of which are similar to those mentioned in (*a*).

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* Sir J. Prestwich, "On the occurrence . . . at Ightham, Kent," *Quart. Journ. Geol. Soc.*, vol. xlv, p. 171. "Excursion to Ightham," *Proc Geol. Assoc.*, vol. xi, p. 66. W. J. L. Abbott, "Excursion to Basted and Ightham," *Proc. Geol. Assoc.*, vol. xiii, p. 157.

† *Cf.* "Excursion to Down," *Proc. Geol. Assoc.*, vol. xii, p. 393.

(*c*) The gap north of Merstham is 439 ft. O.D. at its lowest point. On its sides at 624 ft. O.D., clay, with flints containing also flint pebbles, and pieces of ironstone occur, while at 560 ft. to 580 ft. O.D. pieces of Lower Greensand Chert are found.

(*d*) Extensive beds of gravel occur at Headley Heath,[*] 630 ft. O.D., with similar constituents. These have been ascribed to fluviatile agency by Sir J. Prestwich and Mr. H. W. Monckton.

(*e*) At Burgh Heath, 550 ft. O.D., on the watershed of the Wandle, a similar deposit occurs.

(*f*) At West Wickham,[†] 261 ft. O.D., Mr. G. Clinch, A. S. Kennard, and myself have obtained Palæolithic implements from the fields.

(*g*) The extensive gravel deposits near Croydon, Thornton Heath, Mitcham, etc., all show evidence of derivation from the south by means—partially at least—of the old Wandle.[‡]

(*h*) Mammalian remains, where found in the Drift deposits, always occur at levels not more than about 100 ft. above the level of the present streams. The following are instances:—

At Whiteleaf, 310 ft. O.D., *Elephas primigenius*, *Equus caballus*, *Rangifer tarandus*, *Rhinoceros leptorhinus*, *Bos primigenius* have been found.[§]

At Mitcham others occur. *Cf.* Dr. G. J. Hinde's paper on this subject.

A. 8. The Mole Gap.

Next to the Medway the Mole has succeeded in capturing the greater number of anti-dip and longitudinal streams in the north part of the Weald. The cutting off of the head stream of the Wandle has led to an increase in the drainage area of the Mole. The deposits at Headley and Burgh Heaths already referred to are in close proximity to this gap, and may have derived some of their material from the Mole at an early stage of its career.

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[*] H. W. Monckton, "Excursion to Betchworth and Headley," *Proc. Geol. Assoc.*, vol. xiv, p. 124. W. Whitaker, "Excursion to Kingswood," *Proc. Geol. Assoc.*, vol. xv, p. 415. *Cf.* also *Proc. Geol. Assoc.*, vol. xvi, p. 155.

[†] G. Clinch, "Note on the Gravels at West Wickham, Kent," *Quart. Journ. Geol. Soc.*, vol. lvi, p. 8.

[‡] *Cf.* Dr. G. J. Hende, "Notes on the Gravels of Croydon and its neigbourhood," *Trans. of the Croydon Microscopical and Natural History Club*, 1896-7.

[§] *Cf.* W. W. Watts, *Quart. Journ. Geol. Soc.*, vol. lv, p. 2. W. Whitaker and E. T. Newton, "On a Drift Deposit at Carshalton," *Trans. of the Croydon Microscopical and Natural History Club*, 1889, p. 288.

Details:

(*a*) Ranmore Common on the west side of the gap, 616 ft. O.D., is capped by a superficial deposit containing Lower Greensand débris, flint, etc. A similar deposit occurs on Juniper Hill on the east side.

(*b*) On St. George's Hill, 1½ miles south of Weybridge and 245 ft. O.D., and separated from the main mass to the south by denudation, is a superficial deposit 10 ft. thick, consisting of Tertiary flint-pebbles, subangular flints, Lower Greensand Chert, well-worn pieces of ironstone, and small quartz-pebbles, all derived from the south. Large sarsens are also present. It is about 195 ft. above the present Mole.*

A. 9. The Country Between the Mole and Wey Gaps.

The North Downs in this area decrease in height rapidly. Besides clay with flints other superficial deposits occur at Netley Heath and Newland's Corner.

Details:

(*a*) At Netley Heath, 600 ft. O.D., is a superficial deposit containing much sand with gravel, in which Lower Greensand Chert, quartz pebbles, sandstone, etc., occur.†

(*b*) At Newland's Corner, at a slightly lower level, is a clayey deposit 10 ft. thick, with scattered pieces of the rocks mentioned in (*a*).

A. 10. The Wey Gap

I know of no well-defined high level gravel connected with this gap, nor have I found any record of such.‡ This is due to the Wey being a comparatively recent stream that has encroached on the basin of an older stream which at one time flowed through the Crondall Gap (now dry) to the west. The many Palæolithic implements found at considerably high levels round Farnham point to this conclusion.

Details:

(*a*) At Wrecklesham,§ 360 ft. to 380 ft. O.D., and about 150 ft. above the Wey, is a deposit containing flints, Tertiary flint pebbles, ironstone, Lower Greensand Chert, and small quartz pebbles. It is 25 ft. thick, and has yielded many Palæoliths.

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* *Cf.* Also W. H. Hudlestone, "On a Section through Walton Common exposing London Clay and Plateau Gravels," *Quart. Journ. Geol. Soc.*, vol. xlii, p. 147.

† *Cf.* "Excursion to Netley Heath and Newland's Corner," *Proc. Geol. Assoc.*, vol. xvi, p. 514.

‡ *Cf.* R. A. C. Austin, "On the Gravel Beds of the Valley of the Wey," *Quart. Journ. Geol. Soc.*, vol. vii, p. 278.

§ *Cf.* "Excursion to Farnham," *Proc. Geol. Assoc.*, vol. xiii, p. 74, and in *Proc. Geol. Assoc.* for 1904.

(*b*) At 300 ft. O.D. another terrace occurs consisting of similar material, but only a few implements occur.

(*c*) At 250 ft., near Farnham, a third terrace occurs, in which water-worn flint implements are found.

(*d*) Palæolithic implements have also been found at Godalming.*

A. 11. The Country west of the Wey Gap in the Superficial Deposits of which débris from the Wealden area occurs.

The Hog's Back, which rises to 469 ft. O.D., is free from drift, but a series connected with the Crondall Gap, which lies to the south of Aldershot, occurs to the west of it. Communication with the Wealden area south of this gap has been cut off by the extension of the Wey valley. To the north, in the Bagshot country, superficial deposits are abundant, and, owing to the soft character of the subjacent beds, the various terraces of gravel at different levels are very distinct. If the general declension in height both of the chalk slope and the lower beds forming the western side of the Wealden dome be considered, it is only to be expected that a gap should occur through which the drainage of the west side of the Wealden dome and the high chalk country bounding the Hampshire basin should enter the Thames valley. Another point is brought out in this area. Sir J. Prestwich considered that the gravels included in his "Southern Drift" were of fluviatile origin, and that between the deposition of the higher gravels and the lower river gravels, earth-movements had taken place. Mr. H. W. Monckton, who has minutely examined this district, has come to the same conclusion, and gives, as evidence of the latter, that in one section the gravels and the underlying strata have both been tilted toward the south.

Details:

(*a*) At Upper Hale, 615 ft. O.D., is a deposit about 12 ft. thick, containing, besides flint, ironstone, hard compact sarsen stone, fragments, small quartz, jasper, and a little Lower Greensand Chert. The quartz, jasper, etc., are very similar to those found at Well Hill on the Darenth Gap, and also to the pebbles found in the Wealden Sandstones near Tunbridge Wells, etc.† Dr. G. Abbott has made a collection of pebbles from the sandstones in the Wealden area, which I have examined, and find that many of them can be matched from high level gravels such as those under consideration.

At a slightly lower level large sarsens occur at Upper Hale, etc. Similar gravels occur at Hungry Hill, 577 ft.

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* *Nature*, vol. xliii, p. 345.

† *Cf. Geol. Mag.* for 1878, p. 287.

O.D., Cæsar's Camp, 600 ft. O.D., and Beacon Hill, near.

Mr. S. V. Wood, junr., included these deposits in his "Gravels of the Greatest Submergence."

(*b*) Other sections at lesser heights occur on the Chobham and Frimley ridges, 415 ft. to 350 ft. O.D., Gravel Hill near East Hampstead, 400 ft. O.D., the Hertford Bridge Flats, 333 to 300 ft. O.D., Ascot Heath, 307 ft. O.D.[*]

These deposits point to the former existence of much greater fluviatile action than now exists.

As one proceeds west by Hartley Row, 202 ft. O.D., Bramshill and Hazeley, 218 ft. O.D., gravels containing Lower Greensand débris are rare, and it is not found farther west at Hickley, and the Farley Hills near Swallowfield, showing that material from the Wealden area has not reached them.[†]

B. The Wealden Area.

This area, lying to the south of the Chalk escarpment, has been so thoroughly treated by Mr. Topley, in his "Memoir on the Weald," that little may be said here, especially as he found that subaerial weathering and fluviatile erosion were the agents which had moulded the features of this area.

The phenomena observed are all in agreement with the idea expressed when treating of a typical slope of calcareous and other strata.

Anti-dip (obsequent) streams have carried material formerly on the slope to the south into one or other of the longitudinal valleys, and then it has often been carried *viâ* the Gaps on to the lower part of the slope.

In addition to the height O.D. of the superficial deposits within the escarpment, their distance from it is important, and likely to afford some evidence of its rate of denudation.

Details: The following have been selected from a much larger number as being more or less cogent to the present inquiry.

(*a*) Flint drift occurs from 300 ft. to 50 ft. above the Rother near Petersfield.[‡]

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[*] *Cf.* H. W. Monckton "On Some Gravels of the Bagshot District," *Quart. Journ. Geol. Soc.*, vol. liv, p. 184. Prof. Rupert Jones, "The Geology and Physical Features of the Bagshot District," *Proc. Geol. Assoc.*, vol. vi, p. 429.

[†] *Cf.* Dr. A. Irving, "On the Bagshots of the London Basin and their associated gravels," *Proc. Geol. Assoc.*, vol. viii, p. 143. H. W. Monckton, "On the gravels south of the Thames from Guildford to Newbury," *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 30. Dr. A. Irving, "Notes on the Plateau gravels of East Berks and West Surrey." *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 557. Dr. A. Irving, "On past Eocene surface changes in the Thames Basin," *Geol. Mag.*, 1893, p. 211. "Excursion to Winchfield and Wokingham." *Proc. Geol. Assoc.*, vol. xvi, p. 153.

[‡] Sir R, Murchison, "On the distribution of the flint drift of the S.E. of England, on the flanks of the Weald, etc.," *Quart. Journ. Geol. Soc.*, vol. vii, p. 349.

(*b*) Flint pebbles are found in the gravels of the Medway and Stour Valleys.[*]

(*c*) At East Malling, Heath in the Medway area, gravels occur at 328 ft. O.D., or 308 ft. above the Medway. Tertiary flint pebbles, Lower Greensand Chert, Kentish Rag, and Wealden Sandstone pebbles occur in it.[†]

(*d*) West of Barming Heath,[‡] 250 ft. O.D., or 225 ft. above the Medway, similar deposits occur.

(*e*) At Limpsfield,[§] on the watershed of the Darenth and the Mole, is a thick bed of gravel 526 ft. O.D., consisting of Tertiary flint pebbles and subangular flints. A flint implement has been found here. The presence of the Tertiary outlier at Worms Heath on the North Down points to the derivation of this gravel from similar deposits, now denuded, by an anti-dip stream.[||]

(*f*) Near Starve Crow farm, between Ightham and Tonbridge, and 235 ft. O.D., gravel containing flints, chert, etc., occur. Similar deposits are found between Hadlow and Goose Green at 137 ft. O.D.

(*g*) Bones of extinct mammalia have been found[¶] in superficial deposits of lesser altitude, or near the escarpment, *e.g.*, the Bayle, Folkestone,[**] the Ightham fissure,[††] and Broughton.

SUMMARY OF A AND B.

The superficial deposits found south of the Thames, just briefly described, bring out the following points, some of which will be of great use in attempting to interpret the far more complex phenomena encountered on the north side of the river.

1. That subaerial weathering and fluviatile erosion can account for the phenomena observed to a great extent, if not entirely.

2. That the materials foreign to the immediate locality, present in the superficial deposits of the slope, have been derived from older strata by fluviatile agency.

3. That the presence of Gaps around which deposits occur, which increase in the complexity of their constituents, with decrease in height and the other phenomena described, point to the denudation of such a slope as was taken for a type in the Introduction.

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[*] *Cf.* W. Topley, *Geol. Surv. Mem.*, "The Weald," p. 289.

[†] W. Topley, etc., "On the gravels of the Medway Valley," *Quart. Journ. Geol. Soc.*, vol. xxi, p. 433.

[‡] *Cf. Weald Memoir*, p. 177, where a section is given.

[§] "Excursion to Limpsfield," *Proc. Geol. Assoc.*, vol. xi, p. 82.

[||] *Cf.* W. Topley, "Excursion to Limpsfield," *Proc. Geol. Assoc.*, vol. ix, p. 32, and vol. xii, p. 82.

[¶] *Cf. Nature*. vol. xxiv, p. 30.

[**] S. J. Mackie, "On a deposit at Folkestone containing bones of Mammalia," *Quart. Journ. Geol. Soc.*, vol. vii, p. 257.

[††] W. J. L. Abbot and E. T. Newton, "The ossiferous fissures deposits in the valley of the Shode, etc.," *Quart. Journ. Geol. Soc.*, vol. l, p. 171.

4. That the sources of all the material found can be satisfactorily accounted for, and that the amount of observation which has been expended on this subject precludes the possibility of any further material of a different character having been transported by fluviatile or other agency across to the area on the north side of the Thames Basin.

5. That the following general "Drift Series" for this area is justified, and can in a general way be used for comparison with other series obtained in a similar manner in areas not too far distant.

(*a*) The higher parts above, about 600 ft. O.D. (or 400 ft. above present watercourses near), contain superficial deposits formed by subaerial weathering only, *e.g.*, Lenham.

(*b*) Just below the above level superficial deposits of fluviatile origin are found, consisting of materials derived from the south mixed with local material, *e.g.*, Cobham Park, Well Hill, Headley Heath, Upper Hale. There is some indication that the deposits at the last of these have been affected by subsequent earth-movements.

(*c*) There is an apparent break in the heights at which well-defined superficial deposits are found, the next series occurring about 250 ft. to 200 ft. above present water courses, *e.g.*, the gravels at Thornton and Blean Woods, Stroud Hill, St. George's Hill, near Weybridge, the Bagshot Ridges, etc. Below these a fairly constant series more and more connected with the present valley system occurs. The possibility of this break being due to the earth-movements previously referred to at once suggests itself. The occurrence of large blocks at this stage is noteworthy.

(*d*) Below the above, deposits occur which contain evidence of man and the Pleistocene mammalia. If these latter be closely studied the character of the fauna gradually approaches to its present state, as the height above the present neighbouring watercourses diminishes.

C. Basins of the Loddon and the Kennet.

The superficial deposits in this area are marked by their local derivation. Lower Greensand Chert and other débris from Weald deposits are absent. The basin of the Kennet has been curtailed on the west and north by the cutting back of the Chalk escarpment, but, as no material from the strata below the Cretaceous has been observed or recorded, it seems extremely probable that no tributaries of the Kennet ever flowed over such strata.

Details:

(*a*) At Meadstead, 700 ft. O.D., on the watershed between the Thames and Hampshire basins, Clay with flints, containing also Tertiary flint pebbles, and small quartz pebbles, occurs.

(*b*) On Snelsmore Common, north-west of Newbury[*] and 483 ft. to 429 ft. O.D., is an extensive gravel sheet containing subangular flints, Tertiary flint pebbles, small pieces of sarsen, and a few quartz pebbles.

(*c*) At Inkpen Common, about 480 ft. O.D. and 190 ft. above the Kennet, superficial deposits with large rolled sarsens occur.[†]

(*d*) At Silchester,[‡] 350 ft. O D., and other localities near, similar deposits with sarsens are found.

(*e*) At Donnington, Newbury, 277 ft. O.D., *Bos primigenius* has been found, and at Lambourne railway cutting at a slightly higher level, *Elephas primigenius.*

(*f*) Palæolithic implements have been found in large numbers at Knowle Farm near Savernake.[§]

(*g*) The river terrace gravels near Newbury at low levels have yielded *Elephas primigenius*, *Bos primigenius*, *Bos taurus*, *Sus scrofa*, *Equus caballus*, *Rangifer tarandus.*

Note.—The Kennet at Newbury is 290 ft. O.D.

PART II.

THE SUPERFICIAL DEPOSITS ON THE NORTHERN SLOPES OF THE LOWER THAMES BASIN AND IN THE VALLEY OF THE LOWER THAMES.

D. 1. Preliminary Remarks.

The deposits on the northern slope west of Goring Gap have already been referred to in treating of the Kennet Basin. The general trend of the chalk escarpment there is from west to east, and the superficial deposits contain débris from local sources only. In and around Goring Gap a great change takes place in the character of the material forming the superficial deposits, and to the east the chalk escarpment changes in direction, and for over thirty miles trends to the north-east as far as the Dunstable Downs, after which it decreases in height and becomes less definite

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[*] *Cf.* P. F. Richards, "The gravels and associated deposits at Newbury," *Quart. Journ. Geol. Soc.*, vol. liii, p. 420; also T. Codrington, "On the Drift Beds of the Newbury District," *Mag. of the Wilts Arch. and N.H.S.* for 1865.

[†] *Cf.* "Excursion to Kintbury, etc.," *Proc. Geol. Assoc.*, vol. xvii, p. 388.

[‡] *Cf.* H. W. Monckton, "Excursion to Silchester," *Proc. Geol. Assoc.*, vol. xvi, p. 513; also "Excursion to Winchfield and Hook," *Proc. Geol. Assoc.*, vol. xvi, p. 519.

[§] *Cf.* E. Willet in *Journal of the Anthrop. Inst.*, vol. xxxi (1901).

in character. The 400-ft. O.D. contour line remains unbroken till the Stevenage (or Hitchin) Gap is reached, and that for 300 ft. O.D. continues as far as Suffolk. This is in marked contrast to the way the slope has been cut up on the south side of the Thames Basin.

The Goring Gap is *now* the only way by which streams north of the escarpment can drain into the Lower Thames Basin.* That other communications formerly existed will be evident later. To the east of the Dunstable Downs the superficial deposits for the first time in this inquiry become complicated by the presence of "Boulder Clay." It is not intended to treat of this deposit generally, but only in so far as it is related to the other superficial deposits of the Thames Basin.

One point will require very careful consideration. On the slope to the south of the Lower Thames Basin only material from the south occurs. No northern material is found. On the northern slopes, however, especially in the detached portion described in D. 4, much Lower Greensand Chert occurs.

D. 2. Goring Gap and the "Drift Series" associated with it.

The Thames at Reading is 122 ft. O.D., and superficial deposits, other than those due to subaerial weathering only, are found nearly up to 650 ft. O.D. The higher deposits are of a simple character, and have been included by Sir J. Prestwich† in his Westleton Beds. Nothing of an organic nature has at present been obtained from them. He considered that the quartz and other pebbles, foreign to the locality, which are found in them, were derived through Diestian Beds from the Ardennes. For the following reasons, however, I prefer to include them in a "Drift Series" due to fluviatile agency:

i. In this and other districts in which they occur, there is a marked local gradation in the heights of the deposits.
ii. The complexity of the materials constituting these deposits increases as their height diminishes.
iii. When the superficial deposits north of the Chalk escarpment are examined they are found to contain similar foreign material which has been redeposited by the anti-dip streams in the same manner as the Tertiary flint pebbles in the Wealden area have.
iv. They are usually associated with a lower series of deposits in which there is more evidence of fluviatile action.

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* It may be noted that the Lea rises a little beyond the Chalk escarpment on Lower Cretaceous strata.

† *Cf.* Prof. J. Prestwich, "On the Relation of the Westleton Beds of Suffolk to those of Norfolk and on their Extension Inland," *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 84.

v. In some of these deposits it can be definitely shown that the sources of the constituents lie far to the north of their present position.

Below the above the superficial deposits contain much material derived directly or indirectly from the Bunter Pebble beds of the Midlands.

In the lower gravels Palæolithic implements are plentiful, and remains of many of the extinct mammalia are associated with them.

Lower Greensand Chert from the south occurs in the superficial deposits round this gap up to a considerable height; in fact Sir J. Prestwich records it at 650 ft. O.D. This shows that fluviatile communication with the south side of the present basin of the Lower Thames has existed for a long period. This point is important, and will be further developed in D. 3.

Details:

(*a*) As in previous cases above 650 O.D. subaërial deposits due to weathering only are found consisting of Clay with flints and débris of the Reading Beds.

(*b*) The numerous Tertiary outliers on the Chalk have, in most cases, on their surfaces at 600 ft. to 650 ft. O.D., superficial deposits of a simple character, consisting of Tertiary flint pebbles, subangular flints, pieces of sarsen stone, quartz pebbles, pebbles of dark radiolarian chert, jasper, small pieces of carboniferous chert with crinoid stems, and quartzites, some of which are weathered white throughout, while others have a core of darker material. Lower Greensand Chert is extremely rare. This assemblage differs considerably from that which is found in the higher drifts on the south and west side of the Lower Thames Basin. They may be seen at Nettlebed, Greenmore Hill, Cadmore Common and other places.

(*c*) On Streatley Hill, 550 ft. O.D., in addition to the above, red quartzites from the Midland occur.

(*d*) On Ashley and Bowsey Hills, 467 ft. and 475 ft. O.D., the number of constituents again increases. Dark green pebbles of a rock containing much Tourmaline, dark chert pebbles with much secondary quartz veining occur, while Sir J. Prestwich records Greenstone. Lower Greensand chert from the south is also present and often 3 in. in length.

(*e*) At Goring Heath, in a wood near the Almshouses and 360 ft. O.D., is a deposit upwards of 10 ft. in thickness containing many large blocks of flint, sarsens (11 in. by 9 in. by 6 in.), and quartzites up to 6 in. long.

(*f*) At the Hockett above Quarry Woods, at 351 ft. O.D., is gravel deposit containing in addition many blocks of devitrified rhyolite with large porphyritic felspar crystals. Pieces of a greenish ash also occur.

(*g*) At Norcot on the Tilehurst plateau, 294 ft. O.D., the amount of Bunter débris is very large. The same igneous rocks occur here as in (*f*). One piece of felsite I obtained showed well-marked scratching.

(*h*) Similar deposits occur on Loudwater Hill on the road to Beaconsfield, at 300 ft. O.D., just at the entrance to the Wye Valley. The constituents show signs of wear, especially those of igneous origin. On Stoke Common they again occur. They can also be traced farther eastward through Bucks and Herts (*cf.* next section).

(*i*) At Caversham, 241 ft. O.D., and Grovelands, Reading, 197 ft. O.D., palæolithic implements associated with *Elephas primigenius*, *Rhinoceros*, *Bos primigenius*, *Cervus*, and *Equus* occur.

(*j*) At Maidenhead, 150 ft., palæolithic implements, Musk Ox, etc., have been found.

(*k*) At Kennington Road, Reading, 144 ft. O.D., Hippopotamus major has quite recently been obtained by Mr. L. Treacher.

Only the more salient features of a few of the deposits found in this area have been treated, but numerous other deposits of an intermediate character are met with.*

D. 3. The Country between Goring Gap and the Dunstable Downs.

This tract of country is situated on a slope of chalk on which a few remnants of Tertiary beds remain.

The gaps at Princes Risborough, 427 ft. O.D.; Wendover, 502 ft. O.D.; Tring, a little over 400 ft. O.D., and the simple character of the superficial deposits on the higher ground, show that we are dealing with an area once of greater extent, the dip streams of which have not brought material from older

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* H. J. O. White, "Notes on the Westleton Beds near Henley-on-Thames," *Proc. Geol. Assoc.*, vol. xii, p. 379. "On the Distribution and Relation of the Westleton and Glacial Gravels in parts of Oxford and Bucks," *Proc. Geol. Assoc.*, vol. xiv, p. 11. Dr. J. W. Gregory, "The Evolution of the Thames," *Nat. Science* (1894), vol. v, p. 97. O. Shrubsole, "On Some High Level Gravels in Berks and Oxon," *Quart. Journ. Geol. Soc.*, vol. liv, p. 585. Sir J. Prestwich, "On a Peculiar Bed of Angular Drift and Chalk Rubble on the Lower Chalk High Plain between Upton and Chilton," *Quart. Journ. Geol. Soc.*, vol. xxxviii, p. 127. H. J. Osborne White, "On the Origin of the High Level with Triassic Débris adjoining the Valley of the Upper Thames," *Proc. Geol. Assoc.*, vol. xv, p. 157. O. Shrubsole, "Valley Gravels near Reading," *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 155. W. Whitaker, "Excursion to Goring," *Proc. Geol. Assoc.*, vol. xiv, p. 175. J. H. Blake, 'Excursion to Reading," *Proc. Geol. Assoc.*, vol. xiv, p. 413. *Cf.* also vol. xv, p. 304, and vol. xvii, p. 381. Ll. Treacher, "Excursion to Cookham," *Proc. Geol. Assoc.*, vol. xv, p. 101. J. Stevens, "Descriptive Catalogue of the Reading Museum," Part I. H. J. Osborne White, "Excursion to the Chiltern Hills," *Proc. Geol. Assoc.*, vol. xvi, p. 251. "Excursion to Twyford and the Wargrave Outlier," *Proc. Geol. Assoc.*, vol. xvii, p. 176. "Geology of Reading," *Mem. Geol. Survey.* "Excursion to Henley-on-Thames," *Proc. Geol. Assoc.*, vol. xii, p. 204.

strata to the north or west. This feature is due to the early cutting back of the escarpment and the formation of longitudinal streams which, finding their way into the more successful dip streams (consequents), have formed deeper and wider gaps. No Bunter débris is found in the upper parts of the valleys, and the patches of superficial deposits capping the Tertiary outliers cut across the area, and are connected with those above 600 ft. O.D. at Goring Gap on the one hand, and with those described in D. 5 on the other.* Lying to the south of these higher and older gravels the other members of the Drift series down to the present river terraces as described at Goring Gap are continued across Bucks and Herts where they join the "Drift Series" of the Stevenage Gap. If these are of fluviatile origin, as supposed, then the general direction of drainage must have changed since their deposition, and they may be looked upon as another indication of Earth movements having taken place since the deposition of the higher gravels.

Details:

(*a*) As usual, the superficial deposits which occur above 600 ft. O.D. are of subaerial origin. At Walter's Ash,† 636 ft. O.D. above Bradenham, 332 ft. O.D. in the Wye valley, large sarsens occur embedded in clay, with flints and débris of the Reading Beds. Several of the sarsens have found their way down into the valley below.

(*b*) At Lane End, four miles east of High Wycombe, on a Tertiary outlier at 600 ft. O.D., is a superficial deposit similar to those about the same height described in the previous section.

(*c*) At Cowcroft‡ or Tiler's Hill, near Chesham, Lower Greensand Chert and Hertfordshire Conglomerate occur in a similar deposit.

(*d*) At Penn,§ near Beaconsfield, 547 ft. O.D., another section is exposed.

(*e*) At Coleshill, above Amersham, 500 ft. O.D., dark Radiolarian Chert, Carboniferous Chert, Jasper, Quartz, etc., occur as at Goring Gap.|| Similar deposits occur at Sarratt, Chipperfield, Abbotts Bromley, and Bedmond (near school).

(*f*) At Gerrard's Cross, Gravel Hill, north of Chalfont St. Peter, Chorley Wood, Chenies, Bedmond (near pond), gravels with Triassic débris and flint are found, connecting similar gravels at Goring Gap with those found round the Stevenage Gap.

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* *Cf. Proc. Geol. Assoc.*, vol. xv, p. 87.

† See also the Rev. E. C. Spicer's paper read before the Geological Society on November 9th, 1904.

‡ "Excursion to Cowcroft," *Proc. Geol. Assoc.*, xvii, p. 370, and xv, p. 89.

§ "Excursion to Penn," etc., *Proc. Geol. Assoc.*, xv, p. 311.

|| For a fuller account of the Gravels in Herts and Bucks, see paper read by the Author before the *Herts Nat. Hist. Soc.*, November, 1904.

(*g*) The numerous pipes in the Chalk which are exposed along the railway[*] line through Amersham, Great Missenden, etc., are filled with local material only. Sections also at Tring and Berkhampstead[†] show that the valleys of the Gade and Bulbourne are free from non-local materials. Farther south, however, material from the gravels described in (*f*) appear.

(*h*) Palæolithic implements occur at Caddington, 580 ft. O.D., on an old land surface.[‡]

D. 4. The Hitchin or Stevenage Gap and its Associated Deposits.[§]

To the east of the Dunstable Downs the chalk escarpment, which from Goring Gap has had a general north-easterly trend, undergoes a decided change. Its elevation rapidly diminishes, the general direction is almost due west to east, and some of the superficial deposits on the slope are of an entirely different character. In addition to the débris from local strata with here and there deposits of a similar character to those found at high levels round Goring Gap, numerous scattered deposits are found containing débris from the Lower Mesozoic and Palæozoic formations mingled with those from the Cretaceous and Tertiary. Not only have fragments of hard rock, some of fair size, been transported, but the great Clay formations of the Midlands have added their quota.

The area now under consideration lies between the upper valley of the Lea and that formed by the Granta, a tributary of the Cam (anti-dip stream), flowing northward by Newport.

Details:

(*a*) Along the escarpment near Sundon and Streatley, at heights ranging up to 530 ft. O.D., drift clays and gravels occur. At Streatley, 500 ft. O.D., there are many large boulders of basalt (to 5 cub. ft.), and smaller ones of sandstone, Jurassic limestone, etc. On the opposite side of the gap at Kelshall, Reed, Roe Green, Wallington, and Cumberlow Green, boulders also occur, consisting of basalt, dolerite, Carboniferous limestone, sandstone, etc.[‖] Some have

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[*] *Cf.* "Excursion to Great Missenden and Hyde Heath," *Proc. Geol. Assoc.*, vol. xii, p. 340.

[†] "Excursion to Boxmoor," *Proc. Geol. Assoc.*, vol. xvi, p. 501.

[‡] Dr. H. Hicks, "Prehistoric Man in Britain," *Trans. Herts Nat. Hist. Soc.*, vol. v, p. 147. W. G. Smith, "Primæval Man in the Valley of the Lea," *Essex Nat.*, vol. i, pp. 36, 83, 125. Worthington G. Smith, "Man, the Primæval Savage." Worthington G. Smith, *Nature*, vol. lii, p. 222. Worthington G. Smith, *Nature*, vol. lix, p. 506, and vol. lx, p. 390 "A Guide to the Antiquities of the Stone Age," etc., British Museum, Bloomsbury.

[§] *Cf.* T. E Lones, "The Gravels, Clays, and Loams of Western Hertfordshire," *Trans. Herts Nat. Hist. Soc.*, vol x, p. 153.

[‖] *Cf.* Also H. G. Fordham, "Notes on the Boulder Clay and Boulders of North Herts," *Trans. Herts Nat. Hist. Soc.*, vol. iii, p. 33. J. V. Elsden, "On the Microscopic Structure of the Boulders found in the North Part of Herts," *Trans. Herts Nat. Hist. Soc.*, vol. iii, p. 47.

travelled down the slope, and may be seen at West Mill, near Buntingford, etc.

(*b*) At Offley, 500 ft. O.D., near the windmill, a gravel deposit occurs containing pieces of basalt, both compact and spheroidal; Carboniferous limestone (fossiliferous), dark cherts, quartz pebbles, various quartzites, Jurassic fossils, and one piece of igneous rock very closely resembling, if not identical with Rhomb porphyry.

There is a pit on "Gravel Hill," close to the escarpment, in which similar gravel is found, but the igneous rocks appear to be absent.

(*c*) At Ayot,* north of Hatfield, under a drift clay which is made up of disturbed London Clay in which pebbles from the underlying beds are found, is a gravel deposit, resting on Tertiary Beds, the constituents of which are of the same character as those occurring in high level gravels to the west as far as Goring Gap. On the plateau on which High Barnet, Potters Bar, etc., stand, similar deposits occur and will be considered later.

On the slope itself they occur at Potters Heath, 400 ft. O.D., Barnard's Heath, north of St. Albans, 406 ft. O.D., Harmer Green, 409 ft. O.D., Sacombe Park, 362 ft. O.D., and Colliers' End, 348 ft. O.D.

(*d*) At Codicote, 356. ft. O.D., three miles north of Ayot, is a gravel deposit 30 ft. thick, consisting mainly of flint, some as large blocks, but it also contains Bunter débris, sandstones, quartz, etc., devitrified rhyolite and materials from the higher gravels. Similar deposits occur at Woolmer Green, three miles to the west, and just north of Datchworth Church. A well-worn pebble of Hertfordshire conglomerate 8 ins. long, and 5 ins. broad was found at Woolmer Green, also basalt showing spheroidal structure.

(*e*) About one mile south of St. Albans, at 308 ft. O.D., is a deposit 12 ft. thick, containing much Bunter débris, devitrifred rhyolite, one block measuring 10 ins. by 9 ins., large quartzite pebbles, boulders of Herts conglomerate, and sarsen stone, in addition to many others similar to those found in the higher gravels in this area. To the north of St. Albans, at 340 ft. O.D., and also at The Noke, near Brickett Wood, 300 ft. O.D., similar deposits occur.

(*f*) At Kemp Row, west of Radlett, a little above 300 ft. O.D. Both here and at the localities named in (*e*) much disturbed Clay with flints occurs. Farther west the Tertiary

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* *Cf.* "Excursion to Ayot Green and Hatfield Hyde," *Proc. Geol. Assoc.*, vol. xv, p. 308, also xvii, p. 336. H. W. Monckton, "On a Section of the Westleton Beds at Ayot Brickfield," *Geol. Mag.* (1899), Dec. 4, vol. vi, p. 59.

strata at Woodcock Hill, south of Rickmansworth, and 313 ft. O.D., are capped by a similar deposit.

(*g*) At Bushey, Rickmansworth (near canal and Croxley Green) and Harefield, all about 200 ft. O.D., beds of gravel derived from higher deposits are found about 50 ft. above the Colne. The apparent absence of boulders of basalt, and granite and débris from Jurassic strata in the gravels bordering the Colne valley is noticeable.

(*h*) To the north of Luton and near Leagrave,[*] below the 400-ft. O.D. contour line, and not much above the Lea, is a thick deposit differing in many respects from those already described in the area, except those at higher levels near Offley and Gravel Hill (*cf.* (*b*)). It contains much Jurassic débris, many quartzites, pieces of pink and white granites, schist, hard chalk pebbles, red chalk, carboniferous limestone, etc. Many of the constituents are similar to those occurring north of Buckingham, and described in F 5.

(*i*) Near Welwyn, superficial deposits 20 ft. thick occur, at 279 ft. O.D., and about 20 ft. to 40 ft. above the Mimram, consisting of Clay with flints disturbed, mixed with Bunter and Jurassic débris, granites, schists, spheroidal basalt and other igneous rocks, all derived from higher deposits to the north and north-west.

(*j*) At Hatfield Hyde[†] two beds of drift clay with intervening gravels occur at 289 ft. O.D. Jurassic débris and Carboniferous Limestone, etc., occur.

(*k*) Superficial deposits, with similar constituents to those mentioned in (*h*) and (*i*), occur at Hertingfordbury, just below 200 ft. O.D., Pepper Hill, near St. Margaret's, 165 ft. O.D., Hoddesdon and Broxbourne. The presence of such different materials in these lower gravels is very striking. Farther east at Hunsdon, Netteswell, Latton, etc., all a little above 200 ft. O.D., deposits derived from older gravels occur.

(*l*) Palæolithic implements occur up to about 100 ft. O.D., at Ware, Welwyn, etc.[‡]

It will be necessary to consider the deposits to the south and east of this area before any reasonable induction can be made from the phenomena observed. There are, however, a few points to which attention may be drawn. A new factor has appeared, viz., the presence of what is termed Boulder Clay. In this area it occurs in patches at varying heights on the slope. Farther east it becomes more continuous, as the maps of the

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[*] *Cf.* J. Saunders, "Geology of South Beds," *Geol. Mag.*, 1890, p. 122.

[†] *Cf.* "Excursion to Ayot Green and Hatfield Hyde," *Proc. Geol. Assoc.*, vol. xv, p. 308; also xvii, p. 396.

[‡] W. G. Smith, "Primæval Man in the Valley of the Lea," *Essex Nat.*, vol. i, pp. 36, 83, 125; also "Flint Implements in the Drift," *Mid. Nat.*, vol. iv, p. 20.

Geological Survey well show. This deposit has been taken, more or less tacitly, by geological observers as a datum line, and various other superficial deposits have been referred to as above or below it, and their age deduced thereby. Apart from the danger generally of using such lithological evidence, it is especially inclined to be fallacious in this area for the following reasons:

1. It occurs on the escarpment and on the watersheds of the streams draining the chalk slope as well as at various heights in their excavated valleys. This is no doubt due to slipping, etc., but its value as a datum line is thereby rendered of little value.

2. The composition of the "Boulder Clay" itself, and the character of the rock fragments it contains vary continually.

For these reasons I have in this inquiry paid more attention to the contained rock fragments than to the clay itself. Another point to be noticed is that although "Boulder Clay" occurs on the highest ground on either side of the Stevenage Gap, the débris from it only occurs in the lower gravels. This seems to indicate that fluviatile action had proceeded a long time before its appearance. The rock fragments it contains differ from those found in the higher gravels by the addition of much Jurassic débris, pieces of Carboniferous limestone, pebbles of hard chalk, and many varieties of igneous rock differing widely from the few found in older gravels, and also among themselves. The presence of various kinds of granite, dolerite and basalt, is most marked. Bearing these facts in mind the "Drift Series" for this area for those deposits not due to subaerial weathering only, is as follows:

1. Simple gravels, 400 ft. to 350 ft. O.D., in the more southern portions of the slope, and similar to those found at high levels round Goring Gap, *e.g.*, those at Ayot, Sacombe Green, etc.

2. Gravels made up of local débris mixed with Bunter pebbles, devitrified rhyolite, etc. These occur down to about 300 ft. O.D. Gravels similar to those described in (1) and (2) can be traced across Herts and Bucks to Goring Gap.

3. Various deposits, more or less connected with the present river system below 300 ft. O.D., and containing Jurassic and other débris from the Boulder Clays and Gravels found on the northern part of the slope up to 500 ft. O.D.

It appears, then, that after the deposition of the gravels connected with the "Drift Series" at Goring Gap the main line of drainage was changed and passed to the south of its original position. The present tributaries of the Thames on its north side have cut across the original line of drainage. As the gravels described in (3) contain Boulder Clay débris, and those in (1) and (2) not, this deposit must have been introduced at about the same time as the change in drainage.

D. 5. The Chalk Slope East of the Bishop Stortford Gap.

The higher ground in this area is almost all below 400 ft. O.D., and declines in height to the north and north-east till the 100-ft. O.D. contour line forms approximately the southern boundary of the valley of the Waveney and Little Ouse, the waterparting of which at Lopham Ford is only 83 ft. O.D. The Boulder Clay as seen from the Survey Maps covers most of this district, and what other superficial deposits occur at elevations above 300 ft. O.D., appear to be derived from it.

In traversing the country between Saffron Walden, Thaxted, Great Thurlow, Great Bradley, Bury St. Edmunds, Chedburgh, Sudbury, Hedingham, Claydon, Crowfield, Debenham, etc., I was unable to find any sign of deposits of a different character, neither have I been able to find any records of such. It is therefore extremely probable that most of the materials mentioned in the next section were not derived from this area but *viâ* the Gap at Stevenage.

At lesser elevations a series of deposits having a general west to east trend, and connected with the deposits found round the Hitchin Gap occur. Although these are situated on the gentle slope which extends from the Chalk escarpment to the coast they will be better understood if taken by themselves, after treating of an extensive area not at present connected with either the northern or southern slopes of the Thames Basin.

D. 6. Parts of Middlesex, South Hertfordshire and Essex, on the north side of the Lower Thames Basin, not at present connected with either the northern or southern slopes.

This area, which has been much affected by denudation, extends from the east side of the Colne valley to the North Sea. It is divided into two unequal portions by the valley of the Lower Lea. In the western portion much of the surface is over 400 ft. O.D., and reaches its highest point at Stanmore Common, 503 ft. O.D. Superficial deposits cover most of this higher ground, which is free from "Boulder Clay."

The eastern portion is traversed by the River Roding, which flows in a general south-westerly direction into the Thames near Ilford, and by the Wid, which flows in a north-westerly direction into the Cam, which is itself a tributary of the Chelmer. The general elevation of the land decreases eastward, the highest point being at High Beech, Epping Forest, which is 376 ft. O.D. To the north it is separated from the northern slope of the Thames Basin by a belt of lower ground, which will be considered in the next section, D. 7. Boulder Clay at slightly lower levels than the gravel deposits is also present.

The position and character of the deposits in this area situated on high ground between the two chalk slopes renders them of great use in interpreting the superficial deposits of the Lower Thames Basin.

Details west of the Lea Valley:

(*a*) Stanmore Common,* 503 ft. O.D, the highest ground in Middlesex, is capped by gravel of similar character to that already described as occurring at high levels to the west as far as Goring Gap. Tertiary flint pebbles, subangular flints, quartz pebbles, jasper, radiolarian chert, Herts conglomerate, blanched quartzites, etc. Red quartzite pebbles, in addition, are found at Harrow Weald about 400 ft. O.D. one mile to the south. Similar gravels also occur at Arkley, west of High Barnet at 463 ft. O.D. Lower Greensand Chert which occurs plentifully in the lower gravels of this area is not found in these higher deposits.

(*b*) At High Barnet, 400 ft. O.D., is a well-defined sheet of gravel 6 ft. to 14 ft. thick, containing in addition to those named in (*a*), quartz pebbles in great variety, radiolarian chert with much secondary quartz veining, grits, red and other quartzites, pieces of Carboniferous Chert with crinoid stems, hard compact sarsen stone with rootlets, etc. Besides these there are numerous pieces of Lower Greensand Chert to which special attention must be drawn. The study of the deposits and the Lower Greensand of the Midlands has convinced me that these fragments have not come from that direction. Such a rock has not been detected in the Lower Greensand area of Bedfordshire, and also it does not occur in the superficial deposits on the northern slope. It is, therefore, extremely probable that it is of southern origin. It occurs in the various high level superficial deposits to the south, such as Swancombe Hill, the Langdon Hills, Rayleigh, etc. As in the high level deposits on the south slope of the Thames Basin, it is associated with the small varieties of quartz, jasper, etc., previously described. If this view be correct, and that the deposits in which this rock is found north of the Lower Thames Basin are of fluviatile origin, it follows that the slope of the Wealden dome once extended much farther north, and that these northern deposits have been cut off from the southern slope either by denudation alone, or denudation combined with earth-movements. It also implies that what is now the Lower Thames Valley is of recent geological age.

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* *Cf.* "Excursion to Stanmore," *Proc. Geol. Assoc.*, vol. xvii, p. 175. C. Reid, "Record of Progress," 1899, p. 140.

(*Cf.* The similar result arrived at in D. 3). The view should receive corroboration when treating of the deposits which lie between the area now being considered, and the northern slope of the Thames Basin, and also when treating of the deposits in the Lower Thames Valley itself.

(*c*) At Hampstead Heath,[*] 412 ft. O.D., Highgate,[†] Totteridge, 400 ft. O.D., and South Mimms Wood, 400 ft., similar deposits occur.

(*d*) At Bell Bar, two miles south of Hatfield, and 360 ft. O.D., the complexity and size of the constituents increase greatly. Devitrified rhyolite and the greenish ash associated with it at Goring Gap again appears, Carboniferous Chert, various Bunter quartzites, etc. Similar deposits occur at Bayford and Hertford Heath, 300 ft. O.D.[‡]

(*e*) At Newgate Street[§] and Brickenden Green to the north of the area much Lower Greensand Chert occurs.

(*f*) At Hendon, 280 ft. O.D., much southern material, such as sarsen, Lower Greensand Chert, etc., are found beneath the local Boulder Clay which has been shown by Dr. Hicks to be made up of disturbed London Clay.[||]

(*g*) On Horsendon Hill, 278 ft. O.D., south of Harrow, much Lower Greensand Chert occurs.[¶]

One observation I made in this area seems to point to earth-movements as being one factor in bringing about the present state of things. In a lane just below the 400-ft. O.D. contour line leading to the superficial deposit at South Mimm's Wood, the chalk is exposed covered by Tertiary beds which underlie the superficial deposits. Chalk is also found quite close to the surface at Potters Bar station and Northaw. Now on the south side of the Lea Valley, to the north of the above localities and forming part of the northern escarpment of this plateau, the same Tertiary beds are found cropping out along the 200-ft. O.D. contour line. This may indicate a slight gentle fold or a fault.

Another point may be mentioned. The superficial deposit at Bayford, 300 ft. O.D., rests on the London Clay, Mr. W. Whitaker, F.R.S., being my authority for this statement. At a

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[*] *Cf.* "Excursion to Hampstead," *Proc. Geol. Assoc.*, vol. ii, p. 40.

[†] *Cf.* W. J. L. Abbot in *Proc. Geol. Assoc.*, vol. xiii, p. 84.

[‡] *Cf.* Prof. McKenny Hughes, "On Two Plains in Herts," *Quart. Journ. Geol. Soc.*, vol. xxiv, p. 287; "Excursion to Hertingfordbury, Bayford, etc.," *Proc. Geol. Assoc.*' vol. xvi, p. 447; "Excursion to Hatfield and Bell Bar," *Proc. Geol. Assoc.*, vol. xiv, p. 420.

[§] Messrs. H. W. Monckton and R. S. Herries, "Hill Gravels North of the Thames," *Proc. Geol. Assoc.*, vol. xii, p. 108.

[||] Dr. H. Hicks, "On some Recently Exposed Sections in the Glacial Deposits at Hendon," *Quart Journ. Geol. Soc.*, vol. xlvii, p. 575; "Excursion to Hendon and Finchley," *Proc. Geol. Assoc.*, vol. xii, p. 334 and vol. xiv, p. 328; "Excursion to North Finchley and Whetstone," *Proc. Geol. Assoc.*, vol. xiii, p. 367.

[¶] J. V. Elsden, "On the Post Tertiary Deposits in Hertfordshire," Trans. *Herts Nat. Hist. Soc.*, vol. i, p. 103; T Belt, "The Superficial Gravels and Clays around Finchley, Ealing and Brentwood," *Quart. Journ. of Science*, July, 1878; H. Walker, "The Glacial Drifts at Finchley," *Geol. Mag.* for 1871, p. 527; "The Glacial Drifts of North London," *Nature*, vol. viii, p. 286; "The Glacial Drifts of Muswell Hill and Finchley," *Proc. Geol. Assoc.*, vol. ii, p. 289.

slightly lower level in the churchyard close by "Boulder Clay" is found which contains large dolerite boulders. If these movements have taken place this Boulder Clay has probably been included with them.

East of the Lea Valley.

Many Bagshot outliers occur in this district, and the superficial deposits resting on them are largely made up of débris from them. Lower Greensand débris is generally present, but the other constituents found in the high level deposits west of the Lea are rare, the number of them decreasing as the gravels are traced eastward. Mr. S. V. Wood, junr,[*] Sir J. Prestwich,[†] and Mr. H. W. Monckton,[‡] have treated of these deposits in numerous papers.

Details:

(*a*) On the Epping Forest[§] ridge, 376 ft. to 340 ft. O.D., sections occur near High Beech, Copt Hall, Jack's Hill, Coopersale Common, etc. The following rock constituents are present: Lower Greensand Chert, small quartz pebbles, radiolarian chert, jasper, a few red quartzites, Tertiary flint pebbles, and subangular flints.

(*b*) At Buckhurst Hill, Havering-at-Bower, 313 ft. O.D., Brentwood, 300 ft. O.D., Warley, 378 ft. O.D., Billericay, 319 ft. O.D., Kelvedon, 339 ft. O.D., and many other localities situated on the Bagshot beds[||] deposits occur consisting almost entirely of débris from that formation. This is due in all probability to the area not receiving streams either from the west or south, being at the time of the deposition of these deposits situated on a slope away from gaps like the corresponding beds on the south side of the Thames at Shooter's Hill, etc.

(*c*) Farther west on the Langdon Hills,[¶] 378 ft. O.D., Rayleigh, 260 ft. O.D., and in the superficial deposits north of the river Crouch at Southminster, Asheldham and Bradwell, Lower Greensand Chert, and small quartz, etc., reappear.

(*d*) At lower levels the superficial deposits contain northern material obtained by way of the Lea, Roding, etc., which have cut their way back through this area of soft strata,

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[*] S. V. Wood, junr., "The Structure of the Post-Glacial Beds in the Thames Valley, etc.," *cf.* MS. in the Library of the Geological Society (1867). For a full list of Mr. Wood's papers, *cf. Geol. Mag.*, 1885, p. 140.

[†] Sir J. Prestwich, "On the Relation of the Westleton Shingle to the other Pre-Glacial Drifts in the Thames Basin, and on a Southern Drift, etc.," *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 155.

[‡] *Cf.* H. W. Monckton and R. S. Herries, "On some Bagshot Beds and Pebble Gravel," *Proc. Geol. Assoc.*, vol. xi, p. 13.

[§] *Cf.* T. Hay Wilson, "Notes on the Gravels of Epping Forest," *Essex Nat.*, vol. vii, p. 74. "Excursion to Epping Forest," *Proc. Geol. Assoc.*, vol. xiv, p. 339.

[||] *Cf.* H. W. Monckton and R. S. Herries, "On some Bagshot Beds and Pebble Gravel," *Proc. Geol. Assoc.*, vol. xi, p. 13.

[¶] *Cf.* "Excursion to Langdon Hills," *Proc. Geol. Assoc.*, vol. x, p. 489.

and tapping the streams to the north have brought northern material into this portion of the Lower Thames Valley. These, together with the small patches of boulder clay will be further considered in treating of the present Lower Thames Valley.

The study of this area has shown:

i. The extreme probability of the former further extension of the southern slope of the Thames Basin.

ii. The probability of earth-movements having taken place since the deposition of the higher deposits.

iii. That there was at one time a fluviatile connection with Goring Gap.

iv. That the Lower Thames and the Lea, etc., must necessarily be of recent formation, geologically speaking.

We are now in a position to treat of the deposits north of this area, and south of the general chalk slope.

D 7. The parts of Herts, Essex and Suffolk lying south of the Chalk slope east of the Hitchin (or Stevenage) Gap, and north of the district described in D 6.[*]

In this area the country to the north is more or less covered by Boulder Clay, which deposit extends towards Norfolk, gradually decreasing in height from 510 ft. O.D. above Buntingford down almost to sea level. Just above Bishop's Stortford a pass occurs just above the 300-ft. O.D. contour line, and a long anti-dip stream flows northwards into Cambridgeshire, whilst southward the Stort flows into the Lea.

To the south, the area capped by superficial deposits derived partially from strata south of the present Thames, extends from Stanmore, 503 ft. O.D., and gradually decreases in height to almost sea level at Bradwell.

The Colne Valley now intervenes between the western portion of the Chalk Slope, and the Lower Lea has cut its way back

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[*] *Cf.* Dr. J. Mitchell, "On the Drift from the Chalk and the Strata below the Chalk in Norfolk, Suffolk and Essex," *Proc. Geol. Assoc.*, vol. iii, No. 59, p. 3. S. V. Wood, junr., "On the Pebble Beds of Middlesex. Essex, etc.," *Quart. Journ Geol. Soc.*, vol. xxiv, p. 46; "On the Upper Tertiaries of Copford, Essex," *Quart. Journ. Geol. Soc.*, vol viii, p. 235. S. V. Wood, junr., "On the Structure of the Valleys of the Blackwater, and of the Crouch, and of the East Essex Gravel," *Geol. Mag.*, vol. iv, pp. 276, 348. Dr. A. Irving, "On the Geology of the Stort Valley," *Proc. Geol. Assoc.*, vol. xv, p. 224; "Excursion to Bishop Stortford," *Proc. Geol. Assoc.*, vol. xv, p. 193; *cf.* also B A. Report, 1904. *Mem. Geol. Survey*, Sheet 47. N.W. Essex and N.E. Herts, etc., 1878. S. V. Wood, jun., "On the Red Crag and its Relation to the Fluvio-marine Crag, and on the drift of the Eastern Counties," *Annals and Mag. of N.H.*, Third Series, vol. xiii, p. 185 *Cf.* S. V. Wood. jun., "Further Remarks on the Origin of the Valley System of the South Eastern half of England, prompted by the result of a boring near Witham, Essex," *Geol. Mag.*, Dec. 2, vol. ii. p 500. S. V. Wood, jun., "On the Formation of the River and other Valleys in the East of England," *Phil. Mag.*, vol. xxvii, p. 180; "Structure of the Valleys of Essex," *Geol. Mag.*. vol. iii. p 348. W. Penning, "Notes on the Physical Geology of East Anglia during the Glacial Period," *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 191.

northwards to it. From the evidence of the deposits in these valleys they may be looked upon as recent features.

It is suggested that the former general course of fluviatile action in this area, enclosed on three sides as shown above, was to the east—*i.e.*, towards the Crag area of Suffolk. If such be the case, the superficial deposits of this area should show evidence of such, and form parts of a "drift series," such as has been already described in other areas.

Details:

(*a*) Cutting across the lower portions of the northern slope, regardless of the present system of drainage, is a scattered series of deposits of the same general character as those already traced from Goring Gap to the edge of the Stort Valley. They can be seen in the following localities:—

i. Stort Hill, east of Bishop's Stortford, 290 ft. O.D.

ii. Great Easton, south of Thaxted, near the 300 ft. O.D. contour line, where the following constituents occur: Lower Greensand Chert, quartz pebbles, radiolarian chert, jasper, greenish pebbles containing tourmaline, Carboniferous Chert, and a much weathered igneous rock resembling rhyolite. Sandy deposits referred by the Geological Survey to the Crag occur close by.

iii. To the north of Stebbing,[*] about 250 ft. O.D., superficial deposits of a similar character are numerous, and are in some cases overlain by Boulder Clay. One section near Bran End was 8 ft. deep, and contained many pieces of rhyolite, a greenish ash, and a few typical red quartzites, but nothing derived from Jurassic rocks, or any basalt or dolerite.

iv. At Barnston, south-east of Dunmow, slightly lower than iii., much rhyolite occurs in a similar gravel.

v. At Great Saling the same deposit occurs under Boulder Clay.[†]

vi. At Barrett's Hall, near Little Maplestead, above 200 ft. O.D., the same assemblage of quartz pebbles, radiolarian chert, weathered quartzite, Carboniferous Chert, jasper, and devitrified rhyolite occur.

vii. Sir J. Prestwich[‡] records similar gravel one and a-half miles north of Coggeshall, and at Elmsett, eight miles west of Ipswich, 200 ft. O.D., and several places to the east as far as Westleton Heath, 89 ft. O.D.,

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[*] *Cf.* J French, "On some Plateau Deposits at Felstead and Stebbing," *Proc. of the Essex Field Club*, vol. vi, p. 132. *Cf.* also *Essex Nat.*, vol. iii, p. 210.

[†] *Cf.* J French, "On Some Plateau Deposits at Felstead and Stebbing," *Proc. of the Essex Field Club*, vol. vi, p. 132. *Cf.* also *Essex Nat.*, vol. iii, p. 210. "On the Occurrence of Westleton Beds in Parts of North-east Essex," *Essex Nat.*, vol. v, p. 210.

[‡] *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 84, etc.

and Dunwich*, where it is well shown in pit sections and in the cliffs. To show how the constituents of this set of gravels have remained constant, allowing for local additions, from Goring Gap to this point, I will give a list of the pebbles and rock fragments found at these two last localities. They are quartz pebbles, dark radiolarian chert, weathered quartzites, jasper, dark Carboniferous Chert, and the peculiar glassy red quartzites found in these deposits. Decayed igneous rocks occur in small quantities which may be rhyolite, but my specimens are too weathered for recognition as such. At Dunwich this deposit is seen to rest on decalcified sands belonging to the Red Crag, a marine deposit, and it is quite possible that the gravel above them was deposited under sea water.

(*b*) Lying to the south of the above and towards the centre of the area under consideration, is a series of deposits containing much Bunter débris and connected with the deposits found round the Hitchin or Stevenage Gap.

i. Between Hatfield Heath and Little Laver, 240 ft. O.D. to 217 ft. O.D., many gravel patches occur containing derived material from the set of gravels described in (*a*), together with many Bunter quartzites of various colours, blocks of Herts conglomerate, some 10 in. long, large flint pebbles, hard sarsen fragments, etc. A similar gravel occurs near Hockerill, at 220 ft. O.D.

ii. At Stondon Massey, south-east of Ongar,† and well above 200 ft. O.D., a similar assemblage occurs together with Lower Greensand Chert derived to the south.

iii. To the south of Norton Heath, at 300 ft. O.D., many large blocks occur, consisting of quartzites, quartz, flint, and conglomerate.

iv. South of Great Leigh, Essex, 217 ft. O.D., about 11 miles north-east of iii., the same kind of deposit occurs, but the material is smaller.

v. On the isolated hill at Danbury, which rises to 353 ft. O.D., gravel occurs, the principal sections, however, occur just below 300 ft. O.D. All the varieties of rock named above are found here, and many are covered with dendritic growths of manganese dioxide. The gravels are tilted considerably. This cannot be by the presence of chalk beneath, as

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* *Cf. Mem. Geol. Survey*, Sheet 49 N. "Southwold," etc., by W. Whitaker (1887). *Cf.* F. Harmer, "Excursion to Aldeburgh, Westleton, and Dunwich," *Proc. Geol. Assoc.*, vol. xv, p. 434.

† H. W. Monckton. "Geological Notes in the neighbourhood of Ongar, Essex," *Trans. Essex Field Club*, vol. vi, p. 87.

the strata below consists of London Clay. The digging of a deep well near has disclosed the fact that either a fault or a fold exists here.[*] At a recent excursion to the new railway line between Kelvedon and Tiptree Heath, the London Clay, as shown by bands of septaria, was highly inclined in one of the cuttings. This would account for the exceptional height of the Danbury gravels, and is also another instance of the action of earth-movements since the deposition of the earlier gravels. On the hill above Wickham Bishops similar gravels occur.

vi. The ridge on which Tiptree Heath stands is 267 ft. O.D., and is capped by gravel containing Bunter débris, sarsens, radiolarian chert, rhyolite and the green ash associated with it, Carboniferous Chert with crinoids, etc. Near by, at lower levels at Layer Marney, Birch and Heckfordbridge, gravels of similar composition occur probably derived from older and higher deposits.

vii. These gravels occur again on the high ground north of Brightlingsea,[†] at St. Osyth, and in the cliff sections to the north of Clacton where often in a decayed or worn condition all the types of rock found farther west occur in profusion. I obtained the following: Red quartzites and other Bunter débris, dark radiolarian chert, rhyolite, green ash, quartz, Lower Greensand Chert, Tourmaline pebbles, etc. A few miles north of Clacton, at Walton Naze, a typical[‡] section of the previous class is found at a slightly higher level. Thus this set of gravels can be traced to the coast as in the previous set, but farther south.

(*c*) Between the two sets of gravel described in (*a*) and (*b*), Sir J. Prestwich records superficial deposits between Braintree[§] and Witham, consisting of Tertiary flint pebbles, subangular flints, quartz, Lower Greensand Chert, etc., similar to those described in D. 6, with which it must have been formerly connected.

(*d*) In all the above deposits Jurassic débris is absent, also chalk pebbles, basalt blocks, etc., derived from Boulder Clay. These however are found in the gravels more closely connected with the present valley systems, which in this area trend generally in a north-west to south-east

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[*] *Cf.* S. V. Wood, junr. "Further Remarks on the Origin of the Valley System of the South-Eastern half of England, prompted by the Result of a Boring, near Witham, Essex," *Geol. Mag.*, Dec. 2, vol. ii, p. 500.

[†] *Cf. Mem. Geol. Survey*, Sheet 48, S.-W., Colchester. W. H. Dalton.

[‡] *Cf. Mem. Geol. Survey.* Sheet 48, S.E., Walton Naze and Harwich

[§] W. H. Dalton, "Notes on Geological Rambles in the Braintree District," *Essex Nat.*, vol. v, p. 79.

direction.* At Stanstead station, 280 ft. O.D., are fine sections in a gravel containing Jurassic débris, etc.

In this area then we have:

i. A continuation of the series of gravels which can be traced from Goring and Stevenage Gaps.
ii. A continuation of the series of deposits containing Bunter débris, etc., from the same localities.
iii. A series of deposits derived from the south.
iv. A series of Boulder Clay deposits and others derived from them, which occupy relatively lower levels and contain material from Jurassic strata north of the escarpment.

The first two of these series decreases very gradually in height from about 400 ft. to 300 ft. O.D., near Ayot and Stevenage, to almost sea level, Dunwich and Clacton respectively, but the Boulder Clay deposits range from over 500 ft. at Reed, etc., and are found overlying the first series at Ayot, 400 ft. O.D., but in Essex they are 100 ft. below the deposits with Bunter débris, etc., at Danbury. This much sharper fall and the different direction of the courses of the present streams can be explained by the occurrence of earth-movements subsequent to the deposition of the earlier gravels.

D. 8. Summary for the Northern Side of the Lower Thames Basin.

The study of the superficial deposits in this area bring out the following points:

(*a*) That from the western margin of the Lower Thames Basin, as far as the Dunstable Downs denudation, etc., has proceeded very much on the same lines as in the area on the southern side of that basin. To the east of the Dunstable Downs the superficial deposits give evidence of the influence of other conditions.
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PART III.

THE AREA BETWEEN THE CRETACEOUS AND JURASSIC ESCARPMENTS OF CENTRAL ENGLAND.

F. 1. Preliminary Remarks.

Having shown the nature of the superficial deposits within the Chalk escarpments north and south of the Lower Thames Basin, I now propose to examine those found in the above area.

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Between the Chalk escarpment and the beginning of the Jurassic slope is an area consisting chiefly of comparatively flat land, which is drained by the Avon and Frome in the west, the Middle Thames in the centre, and by the Great Ouse in the east. To the west, where the Cretaceous and Jurassic strata are high, this intervening tract is narrow, but it widens out as these strata decline in height, till the low land about the Wash is reached. The elevated land with Jurassic strata trends north and the Chalk traverses Norfolk at a low elevation, rising again, however, in Lincolnshire, where it has also a northerly trend. This feature is probably due to the gradual decrease in height, which has allowed the escarpment to be more easily cut back and the easier formation of anti-dip (obsequent) streams such as the tributaries of the Cam, Lark, Little Ouse, etc.

The superficial deposits of this area have been studied with the object of ascertaining what light they can throw upon the formation of similar deposits within the Lower Thames Basin. It has been shown that around Goring Gap up to about 650 ft. O.D., and round the Stevenage Gap up to about 500 ft. O.D., deposits occur which contain material foreign to the Cretaceous and Tertiary strata. If these have come through the gaps we should expect evidence of them in the area now being considered.

In connection with the hypothesis set forth in the Introduction, two points should be noticed, first, that the higher the deposits are around the gaps the greater distance it is possible for them to have been derived, and, secondly, owing to the cutting back of the escarpment, it is exceedingly probable that some of the materials will only occur mixed with others introduced at some subsequent period.

direction.* At Stanstead station, 280 ft. O.D., are fine sections in a gravel containing Jurassic débris, etc.

In this area then we have:

i. A continuation of the series of gravels which can be traced from Goring and Stevenage Gaps.

ii. A continuation of the series of deposits containing Bunter débris, etc., from the same localities.

iii. A series of deposits derived from the south.

iv. A series of Boulder Clay deposits and others derived from them, which occupy relatively lower levels and contain material from Jurassic strata north of the escarpment.

The first two of these series decreases very gradually in height from about 400 ft. to 300 ft. O.D., near Ayot and Stevenage, to almost sea level, Dunwich and Clacton respectively, but the Boulder Clay deposits range from over 500 ft. at Reed, etc., and are found overlying the first series at Ayot, 400 ft. O.D., but in Essex they are 100 ft. below the deposits with Bunter débris, etc., at Danbury. This much sharper fall and the different direction of the courses of the present streams can be explained by the occurrence of earth-movements subsequent to the deposition of the earlier gravels.

D. 8. Summary for the Northern Side of the Lower Thames Basin.

The study of the superficial deposits in this area bring out the following points:

(*a*) That from the western margin of the Lower Thames Basin, as far as the Dunstable Downs denudation, etc., has proceeded very much on the same lines as in the area on the southern side of that basin. To the east of the Dunstable Downs the superficial deposits give evidence of the influence of other conditions.

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Batsford Hill, Chipping Norton, Mangersbury Hill, etc., and the districts visited on the Easter Excursion, 1904, but found nothing but local débris. I should therefore think that, if these pebbles have been brought into their recorded positions by natural agencies, they are the scattered remnants of former patches which have been broken up by denudation.

(*b*) At Stone Heath,[*] near Oxford, 535 ft. O.D., is a well-defined bed of gravel 4 ft. to 5 ft. thick, containing numerous large Bunter quartzites, radiolarian chert, rhyolite, such as is found in the Lower Thames Basin, greenish ash, dark pebbles containing much tourmaline, grits, sandstones, etc.

(*c*) At Bagley Wood in the same district, 470 ft. O.D., a road section only was available, but this yielded quartz and radiolarian chert pebbles, light coloured quartzites, etc., so familiar in the higher gravels round Goring Gap. Similar deposits have been described as occurring on Wytham Hill, near.

(*d*) At many localities round the entrance of the Evenlode into the Middle Thames Valley, similar deposits to those described in (*b*) and (*c*) occur, *e.g.*, Ensham Heath, Round Castle Hill, near Bladon, Whichwood Forest, etc.

(*e*) At the Mickleton tunnel, 490 ft. O.D., many large flints and Lias limestone blocks were found embedded in Clay. A few pieces of granite and other igneous rocks were also recorded.

(*f*) At Moreton-on-the-Marsh, and near the Four-shire-stone, 400 ft. O.D., many flints together with Triassic débris occur. The Igneous rocks present include basalt, rhyolite and a few others, much weathered. Jurassic débris appears to be absent.

(*g*) At Handborough, above 300 ft. O.D., in the Evenlode valley, superficial deposits 14 ft. thick occur, and consist mainly of Jurassic débris with a few Bunter pebbles and flints derived from higher deposits.

(*h*) Near Abingdon, about 200 ft. O.D., similar deposits are found. Much broken flint, radiolarian chert, Carboniferous Chert, quartz, etc., occur.

(*i*) At Kirklington, Steeple Ashton, and other localities in the lower part of the Cherwell Valley, and about 300 ft. O.D., Jurassic débris, flint, and well-weathered Bunter pebbles occur.

(*j*) Bones of *Elephas primigenius* and Palæolithic implements occur in the river drifts.[†]

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[*] "Excursion to Cumnor, etc." Prof W. J. Sollas, *Proc. Geol. Assoc.* for 1905.

[†] *Cf. Mem. Geol. Survey*, "Woodstock, etc." A G Bell, "Implementiferous Sections at Wolvercote" (Oxfordshire), *Quart. Journ. Geol. Soc.* for 1904.

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[§] 1900. "The Geological History of the Rivers of East Yorkshire," F. R. Cowper Reed, Sedgwick Prize Essay.

a similar state of things existed in that county. If such were also the case in central England, the Chalk escarpment would be more readily cut back. That overlying Tertiary strata were also probably absent, would lead to quicker denudation of the exposed Calcareous strata by subaerial agencies. Unlike the Wealden area, too, the Jurassic formation is sufficiently elevated to form a bold escarpment, giving a second slope, roughly parallel for several miles, to that of the Cretaceous strata to the south and east. These two slopes agree in that they both gradually decrease in height to the north-east, but the Jurassic slope differs in being less regular, owing to the different divisions of that formation being gradually exposed in that direction, and to the fact that the Jurassic slope and escarpment as a whole trend almost north and south to the east of the Cherwell valley.

Between the Chalk escarpment and the beginning of the Jurassic slope is an area consisting chiefly of comparatively flat land, which is drained by the Avon and Frome in the west, the Middle Thames in the centre, and by the Great Ouse in the east. To the west, where the Cretaceous and Jurassic strata are high, this intervening tract is narrow, but it widens out as these strata decline in height, till the low land about the Wash is reached. The elevated land with Jurassic strata trends north and the Chalk traverses Norfolk at a low elevation, rising again, however, in Lincolnshire, where it has also a northerly trend. This feature is probably due to the gradual decrease in height, which has allowed the escarpment to be more easily cut back and the easier formation of anti-dip (obsequent) streams such as the tributaries of the Cam, Lark, Little Ouse, etc.

The superficial deposits of this area have been studied with the object of ascertaining what light they can throw upon the formation of similar deposits within the Lower Thames Basin. It has been shown that around Goring Gap up to about 650 ft. O.D., and round the Stevenage Gap up to about 500 ft. O.D., deposits occur which contain material foreign to the Cretaceous and Tertiary strata. If these have come through the gaps we should expect evidence of them in the area now being considered.

In connection with the hypothesis set forth in the Introduction, two points should be noticed, first, that the higher the deposits are around the gaps the greater distance it is possible for them to have been derived, and, secondly, owing to the cutting back of the escarpment, it is exceedingly probable that some of the materials will only occur mixed with others introduced at some subsequent period.

F. 2. The Area West of the Evenlode and Middle Thames.

As in the case of the Kennet Basin (E) immediately to the south of this area, almost all the superficial deposits are made up of local material.

On the watershed of the Thames and Avon the presence of scattered quartz, hornstone, grit, etc., is noted in the Geological Survey Memoir of the district.* These may have some connection with the higher gravels round Goring Gap. I was not able to find any in traversing the country between Cirencester and Calne. Flint débris is found at several places some miles north of the chalk escarpment, but as the Jurassic slope is reached, only débris from that formation is found.

The higher parts of the Cotswolds, with the exception of a few stray quartz pebbles,† seem to be free from superficial deposits containing material derived from a distance.‡

Details:

(*a*) At Flintham, near Oaksey, above 300 ft. O.D., flint gravel is found. It is, however, better exposed at Flisterage Wood, on the road to Minety, where there is a gravel 3 ft. thick, consisting of rolled and unrolled flints up to 4 ins. long. Pieces of rolled sarsen stone were present, but no Tertiary flint pebbles. Similar deposits occur near Brinkworth, west of Wooton Bassett, around Malmesbury, etc.§

(*b*) At the foot of the Jurassic slope are superficial deposits with much débris from strata exposed on that slope, and a very little broken flint, which apparently disappears altogether a little farther north. At Raw Hill, between Minety and Cricklade, is a gravel which, in addition to angular and subangular flints, contains many silicified corals, Jurassic limestone, Belemnites, etc.

At Lechlade, Fairford, etc., gravel deposits, 4 ft. to 8 ft. deep, with a little broken flint and much rolled Jurassic limestone are found.

(*c*) At Bourton-on-the-Water in the Windrush Valley is a gravel deposit 10 ft. thick, in which no flint occurs. There seems, therefore, to be in this area only evidence of material from local sources, since if any foreign material had entered the area to any extent it would be found in the superficial deposits.

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* "Geology of parts of Wilts and Gloucestershire," Sheet 34 (1858), p. 44.

† Quartz pebbles occur in places in the Jurassic strata itself, *e.g.*, in the Tilestone at end of Five-mile drive near Chipping Camden. Mr. Richardson, F.G.S., also informs me that there is a thin bed with quartz pebbles in the top bed of the Lower Limestone at Horsepools, near Painswick, Gloucestershire.

‡ E. Hull, "On the Physical Geography and Pleistocene Phenomena of the Cotteswold Hills." *Quart. Journ. Geol. Soc.*, vol. xi, p. 487.

§ *Cf. Proc. Geol. Assoc.*, vol. xiv, p. 341, etc., and vol. xvii, p. 145.

F. 3. The Valley of the Evenlode and the Middle Thames.[*]

The character of the material found in the superficial deposits of this area is entirely different from that described in F. 2, and has engaged the attention of many geologists, including Buckland,[†] Phillips,[‡] Lucy, etc. If a contoured map of the Jurassic slope be examined it will be seen that the escarpment on the west side of the Warwickshire Avon Valley, near Shipston-on-Stour, is suddenly broken, and the 400-ft. O.D. contour line runs round the valley of the Stour and then resumes a north-easterly direction, but it is eight or nine miles to the east of its original position. At this point is situated the low pass, now dry, on which Moreton-on-the-Marsh is situated, just over 400 ft. O.D., and on the watershed of the Stour and the Evenlode. It is to be expected, therefore, that the superficial deposits connected with this pass would be interesting, and they have proved so to geologists for some time past. Mr. Lucy examined this neighbourhood thoroughly. He records the finding of Northern Drift pebbles derived from the Bunter Pebble Beds up to 750 ft. O.D. It must be remembered, however, that the pebbles found at this height were from fields and not from a regular stratified deposit. I have searched for such an one unsuccessfully. Gravel deposits occur at Moreton, and also close by the Four-shire-stone, and can be examined now. In these much débris from Cretaceous and Triassic strata occur, but I did not detect anything from Jurassic beds. In the valley of the anti-dip stream, the Stour, such material is, however, found in abundance. At many localities in the Evenlode Valley similar gravel occurs, but the finest and most interesting deposit I have seen is on the isolated ground near Cumnor, on Stone Heath, at 535 ft. O.D., or 300 ft. above the Thames. This deposit rests on Jurassic strata, and shows that when it was deposited the Cretaceous beds had disappeared.

Details:

(*a*) W. Lucy records scattered pebbles from the Bunter up to 750 ft. O.D., on the sides of the Moreton Gap. I carefully examined much superficial material in road sections, etc., above Long Compton, Stow-on-the-Wold,

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[*] *Cf.* W. Lucy, "The Gravels of the Severn, and Avon, Evenlode, and their Extension over the Cotswold Hills." *Proc. Cot. Club*, vol. v, p. 71; "On the Extension of the Northern Drift and Boulder Clay over the Cotswold Range," *Proc. Cot. Club*, vol. vii, p. 50. S. Buckman, "Gravel at Moreton-on-the-Marsh," *Quart. Journ. Geol. Soc.*, vol. lv, p. 220; see also *Proc. Cot. Club*, vol. xiii, p. 175. E. Witchell, "The Angular Gravel of the Cotswolds," *Proc. Cot. Club*, vol. vi, p. 146. G. C. Gavey, "On the Railway Cuttings at the Mickleton Tunnel and at Aston Magna, Gloucester," *Quart. Journ. Geol. Soc.*, vol. ix, p. 9. W. Lucy, *Proc. Cot. Club*, vol. xi, p. 9. Prof. Hull, *Mem. Geol. Survey*, 1847. S. G. Percival, "On the Occurrence of Schorl in the Drift near Oxford," *Geol. Mag.*, p. 96. See also "On the Occurrence of Pebbles of Schorl Rock from the South-west of England in the Drift Deposits of Southern and Eastern England," by A. E. Salter, *Quart. Journ. Geol. Soc.*, vol. lv, p. 220. "Excursion to Cumnor" etc., Prof. W. J. Sollas, *Proc. Geol. Assoc.* for 1905.

[†] "Reliquæ Diluvianæ," 1823.

[‡] "Geology of Oxford and the Thames Valley."

Batsford Hill, Chipping Norton, Mangersbury Hill, etc., and the districts visited on the Easter Excursion, 1904, but found nothing but local débris. I should therefore think that, if these pebbles have been brought into their recorded positions by natural agencies, they are the scattered remnants of former patches which have been broken up by denudation.

(*b*) At Stone Heath,* near Oxford, 535 ft. O.D., is a well-defined bed of gravel 4 ft. to 5 ft. thick, containing numerous large Bunter quartzites, radiolarian chert, rhyolite, such as is found in the Lower Thames Basin, greenish ash, dark pebbles containing much tourmaline, grits, sandstones, etc.

(*c*) At Bagley Wood in the same district, 470 ft. O.D., a road section only was available, but this yielded quartz and radiolarian chert pebbles, light coloured quartzites, etc., so familiar in the higher gravels round Goring Gap. Similar deposits have been described as occurring on Wytham Hill, near.

(*d*) At many localities round the entrance of the Evenlode into the Middle Thames Valley, similar deposits to those described in (*b*) and (*c*) occur, *e.g.*, Ensham Heath, Round Castle Hill, near Bladon, Whichwood Forest, etc.

(*e*) At the Mickleton tunnel, 490 ft. O.D., many large flints and Lias limestone blocks were found embedded in Clay. A few pieces of granite and other igneous rocks were also recorded.

(*f*) At Moreton-on-the-Marsh, and near the Four-shire-stone, 400 ft. O.D., many flints together with Triassic débris occur. The Igneous rocks present include basalt, rhyolite and a few others, much weathered. Jurassic débris appears to be absent.

(*g*) At Handborough, above 300 ft. O.D., in the Evenlode valley, superficial deposits 14 ft. thick occur, and consist mainly of Jurassic débris with a few Bunter pebbles and flints derived from higher deposits.

(*h*) Near Abingdon, about 200 ft. O.D., similar deposits are found. Much broken flint, radiolarian chert, Carboniferous Chert, quartz, etc., occur.

(*i*) At Kirklington, Steeple Ashton, and other localities in the lower part of the Cherwell Valley, and about 300 ft. O.D., Jurassic débris, flint, and well-weathered Bunter pebbles occur.

(*j*) Bones of *Elephas primigenius* and Palæolithic implements occur in the river drifts.†

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* "Excursion to Cumnor, etc." Prof W. J. Sollas, *Proc. Geol. Assoc.* for 1905.

† *Cf. Mem. Geol. Survey*, "Woodstock, etc." A G Bell, "Implementiferous Sections at Wolvercote" (Oxfordshire), *Quart. Journ. Geol. Soc.* for 1904.

The study of this area, therefore, brings out the following points:

i. That all the materials found in the superficial deposits round Goring Gap can be obtained from the north.
ii. That the rhyolite, radiolarian chert, etc., which occur in so many of the older gravels in the Lower Thames Basin and East Anglia, can be traced as far as Moreton-in-the-Marsh on the edge of the Jurassic escarpment.
iii. That deposits containing Jurassic débris, excluding those due to subaerial weathering, occur at lower levels than those containing only Triassic and older débris.
iv. That the existence of a former easterly or north-easterly longitudinal stream is possible, since Bunter pebbles are found mixed with Jurassic débris in gravels on the eastern side of the area.
v. That all the phenomena observed are in harmony with the working hypothesis as set forth in the Introduction.

F. 4. The Country East of the Middle Thames and Evenlode, mostly included in the Thame* and Cherwell Basins.†

It will be remembered that when treating of the Chalk slope between Goring Gap and the Dunstable Down (D. 3), that in the upper parts of the valleys no material from strata exposed north of the escarpment is met with. The area now under consideration extends northwards of this from the Chalk escarpment to that of the Jurassic strata forming Edge Hill, and is similarly marked by an almost entire absence of non-local material. To the south of Albury is a gravel deposit at 348 ft. O.D., containing quartz pebbles, dark chert (Palæozoic), Carboniferous chert, small red quartzites, jasper, etc. It is very like that found in the higher gravels around Goring Gap, and is probably the deposit of an anti-dip stream, which formerly flowed northward. It has also been shown in F. 3 that Bunter débris occurs to a limited extent in deposits consisting chiefly of Jurassic débris at Bletchington, Kirklington, Steeple Ashton, Heyford, Rowstan, etc., to the east of the Cherwell Valley, at about 300 ft. O.D. This Triassic material may have been derived from older deposits now destroyed. In this district at Finmere, west of Buckingham, is a deposit with much Bunter débris, and in the Drift Clay deposit at Middle Claydon it is again met with. Very little drift seems to have come down the Cherwell Valley from the country north of the Jurassic escarpment. I have looked for it carefully,

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* A. M. Davies, "Contributions to the Geology of the Thame Valley," *Proc. Geol. Assoc*, vol. xvi, p. 15. T. Codrington, "On a Section with Mammaliferous Remains near Thame," *Quart. Journ. Geol. Soc.*, vol. xx, p. 375.

† *Mem. of Geol. Survey*, Sheet 45 (1864), by A. H. Green, p. 53.

in vain, and Mr. Walford, of Banbury, tells me his experience is the same. This supports the view that such Bunter material as occurs in the southern portion of that valley has possibly been derived from the gravels of an old stream having a general easterly direction.

Details:

(*a*) At Newton Purcell, 357 ft. O.D., north-north-east of Bicester, quartzites up to 6 in. long and quartz pebbles occur in a deposit made up chiefly of local material.

(*b*) At Finmere, just below 400 ft. O.D., and about a mile north of (*a*) is a superficial deposit containing Bunter quartzites, dark pebbles containing much tourmaline, radiolarian chert, flint, sandstone blocks up to 8 ins. long. Quite close, but at lower levels, deposits with much Jurassic material occur (*cf.* next section).

(*c*) Two miles south of Albury, 348 ft. O.D., by the side of the Oxford Road, near the "Peacocks," is a small section 3 ft. deep, showing stratified sandy gravel, and containing many broken flints, dark cherts, small quartzites (red, etc.), quartz pebbles, etc., similar to those found in high level gravels at Goring Gap.

(*d*) At Sandy Hill, north-east of Middle Claydon, on the road to Verney Junction Station, is a roadside section containing broken flints, quartz, quartzites, etc. Near this is a large pit showing drift clay over sand. The drift clay contains Bunter débris, in addition to flint, chalk, etc.

F. 5. The Country Drained by the Upper Courses of the Great Ouse, Nen, Welland, and their Tributaries.

The last three sections have dealt with the country drained by tributaries of the Upper and Middle Thames. The present deals with that drained by easterly flowing streams. Some deposits on the watershed of these two systems will be included in the present section.

The chalk escarpment, over 500 ft. O.D., forms a well-marked feature in the south, and is breached by a gap which is just over 300 ft. O.D. at Stevenage. We should expect that similar materials to those found south of this gap would be present in this area. Much drift clay is found, but as it exists at all elevations, and in the river valleys, its use as a datum line is limited. The general trend of the higher ground, north of the Ouse, is from north to south, instead of south-west to north-east, as in the case of the chalk. The probability of a former connection between this area and the last (F. 4), should not be lost sight of.

The superficial deposits observed or recorded north of Buckingham as far as the Jurassic escarpment will be first treated of in order to ascertain what material has come from that direction. Many such deposits occur on the watershed, and in one case at Husbands Bosworth, 500 ft. O.D., there is a stratified deposit 30 ft. thick on the watershed of the Soar, which flows into the Trent; the Swift, which flows into the Severn; the Welland, and the Warwickshire Avon. Such a deposit in such a position is both remarkable and suggestive of great physiographical changes. The highest ground, above 700 ft. O.D, near Arbury Hill, 802 ft. O.D., and the large earthwork, over 700 ft. O.D., north of Barrow-on-the-Hill, etc., are free from any but local débris formed by subaerial agencies due to weathering only, but below that height deposits are found over a wide area containing much derived material. These deposits decrease gradually in height towards the south.

The character of the materials of which they are made up is similar throughout. Bunter débris occurs, also much Carboniferous limestone which is often well-rolled, broken flint, hard chalk pebbles, and pieces of Lincolnshire limestone. Igneous rocks are very rare indeed. I found one block of basalt at Husbands Bosworth, and one or two well-weathered pieces of spheroidal basalt elsewhere. No rhyolite, which is plentiful to the south, occurs. If these deposits are due to any kind of fluviatile action, as their bedded character seems to indicate, then the presence of the Carboniferous limestone points to a former connection across the Trent Valley and the Lincolnshire limestone to a connection with the east. Also in order to account for their position, either great denudation must have taken place since their deposition or denudation combined with earth-movements. The presence also of the same material in the deposits of the Lower Thames Basin points to a further extension south than now exists.

Details:

(*a*) On the high ground east of Leicester many sections in these superficial deposits occur. They have been described by Mr. Deeley.* At Cold Overton, about 600 ft. O.D., is a section 6 ft. deep now open, in which flint, hard chalk, Jurassic limestone, Lincolnshire limestone, brown quartzite pebbles are found. Some of the blocks seen were over a foot long. Spheroidal basalt much decayed was also obtained. Near Knossington at about the same height, weathered red quartzites, white and pink quartz pebbles, rolled gryphœa were found in addition. At Thorpe Scratchville, 492 ft., many Lias limestone blocks occur. Sections are also recorded at Halstead, Tipton, and Skeffington, all above 600 ft. O.D.

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* R. M. Deeley, "The Pleistocence Succession in the Trent Basin," *Quart. Journ. Geol. Soc.*, vol. xlii, p. 437; *cf.* also *Geol. Mag.*, p. 31 (1892).

(*b*) On the high ground south of Market Harborough similar deposits again occur. These, however, are below 600 ft. O.D., but above 500 ft. O.D. At Cold Ashby, the highest point in the area, 661 ft. O.D., no sections occur or are recorded, but at Husbands Bosworth, 500 ft. O.D., the deposit already referred to, consisting of 30 ft. of stratified gravel, under 5 ft. of clay, contains the same materials, but the blocks are larger, many being over a foot long. A block of basalt, 12 ins. by 9 ins. by 6 ins. is interesting, owing to its rarity in these gravels. Scattered about the vicinity are many larger blocks of sandstone, etc., containing 7 or 8 cubic feet.

On the site of the battle of Naseby is a section 10 ft. thick above the 500-ft. contour line. The following rocks were obtained from it: Large broken flints, blocks of Jurassic limestone, hard chalk pebbles, soft chalk, gryphœa incurva, and dilatata, quartz pebbles, red flint, Lincolnshire limestone, radiolarian chert with secondary quartz veining, jasper, red and other quartzites, sandstone, red chalk, Carboniferous limestone, etc. At Naseby itself, just over 600 ft. O.D., many large blocks are scattered about.

At West Haddon, above 500 ft. O.D., similar gravel occurs, described by S. V. Wood, junr., as Mid-Glacial.

(*c*) Near Norton, about two and a-half miles north-east of Daventry, are two sections, 10 ft. deep and at 400 ft. O.D., in the same kind of gravel. The following, in addition to those already mentioned, were found here: Tabular flint, 6 in. long, a pebble of encrinital marble, Carboniferous chert with crinoids, coal, and a small piece of fine-grained pink granite.

(*d*) South of the Nen the same kind of gravel has been recorded at Little Preston (now overgrown). Between Canon's Ashby and Adstone, about 500 ft. O.D., a section 10 ft. deep, covered by a foot of clay. Red Chalk pebbles and spheroidal basalt were found here.

(*e*) To the south of Towcester, as far as Buckingham,* boulder clay and gravels are well developed. The following localities have sections now open: Burcot Wood, 435 ft. O.D., where gravel similar to the above is found. Contortions occur frequently, and are probably due to the large amount of calcareous matter formerly present. A piece of gneiss with pink felspar crystals and a greenish felsite were found here. Similar deposits occur near Silverstone, 359 ft. O.D., Maids Moreton, and especially at Foxcott, 300 ft. O.D., where numerous large Jurassic

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* *Cf. Mem. Geol. Survey*, Sheet 53 S.E. (1860).

localities north of the escarpment. They also occur round the Stevenage Gap, and in many localities in East Anglia as far as the North Sea. On the Chalk slope deposits containing Jurassic débris occur at 500 ft. O.D., but on being traced eastward they descend so rapidly that at Danbury, etc., in Essex, they are 100 ft. below the deposits consisting of Bunter débris and local material only. Also, whereas the latter deposits reach the coast, and are fairly widespread in the eastern parts of Essex and Suffolk, the Boulder Clay with its Jurassic débris, etc , only does near Southwold, and is well developed to the north and south of Lowestoft.

iv. It is worthy of notice that in this area the base of the Cretaceous formation is remarkable for containing an assemblage of igneous and other rocks of unknown origin.* Such material occurs in the Chalk Marl, the Cambridge Greensand and the Lower Greensand. It is true that at the present time, owing to want of sections, but little is seen of them, but sufficient is known to render it possible that some of the material, differing in character from that already shown to exist to the west and south of this area, was derived from this source. In this connection the vast denudation of these deposits as the Chalk escarpment was cut back should be noted. The question is further complicated by the fact that the material known to occur in the Lower Cretaceous deposits is of so varied a character that absolute identification of the several varieties with those occurring in the superficial deposits is very difficult.

v. The formation of the valley system of the Bedfordshire Ouse, subsequent to the cutting back of the Chalk escarpment, has further complicated matters.

Details :

(*a*) At Great Brickhill, over 500 ft. O.D., Bunter quartzites, quartz pebbles, Tertiary flint pebbles, in addition to local material, occur in a deposit 4 ft. thick.

(*b*) At Toddington, 485 ft. O.D., flints but little worn, hard

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* H. Woods, "Boulders in a Coprolite Bed at Stanbridge, South Beds," *Geol. Mag.* 1895, p. 377. H. G. Seeley, "On the Rock of the Cambridge Greensand," *Geol. Mag.*, 1866, p. 302. W. Keeping, "On the Included Pebbles of the Upper Neocomian Sands of the South-east of England, etc.," *Geol. Mag.*, 1880, p. 415. H. G. Fordham, "Notes of a Boulder from the Chloritic Marl of Ashwell, Herts," *Geol. Mag.*, 1883, p. 516; see also *B. A. Reports*, 1883, pp. 136, 505, and 1886, p. 323. A. J. Jukes Brown, "Granite in a Boring at Bletchley," *Geol. Mag.*, 1865, p. 356. C. Reed, "A Handbook to the Geology of Cambridgeshire," Prof. T. G. Bonney, "A Handbook to the Geology of Cambridgeshire," 1877. W. J. Sollas and A. J. J. Brown, "On the Included Fragments of the Cambridge Upper Greensand," *Quart. Journ. Geol. Soc.*, vol. xxix, p. 11. Prof. Morris, "Excursion to Cambridge." *Proc. Geol. Assoc.*, 1871. J. J. H. Teall, "The Potton and Wicken Deposits," "Sedgwick Prize Essay," 1875. W. W. Watts, "Pebble from the Cambridge Greensand," *Geol. Mag.*, 1881, p. 95. A. Harker in *Geol. Mag.*, 1894, p. 566. A. J. Jukes Brown, "The Post Tertiary Deposits of Cambridgeshire." "Sedgwick Essay," 1876. Prof. T. G. Bonney, "On the Microscopic Structure of a Boulder from the Cambridge Greensand, found at Ashwell, Herts," *Proc. Camb. Phil. Soc.*, vol. v, p. 65.

chalk pebbles, Bunter quartzites, Jurassic limestones, and fossils, etc., occur.

(*c*) At Southend Stewkley, 482 ft. O.D., on the waterparting of the Ouse and Thames, is a drift clay with quartz pebbles, radiolarian chert, Bunter quartzites, and Jurassic débris.

(*d*) In Shepherd's Lane, north of Heath and Reach, above 400 ft. O.D., 7 ft. of Boulder Clay resting on the Lower Greensand occurs. The included rock fragments consist of hard chalk pebbles, red chalk, Jurassic débris, gneiss, and mica schist.

(*e*) To the East of Leighton Buzzard, on the Stanbridge Road, above 300 ft. O.D., is a deposit consisting of flint and débris from the Lower Greensand, mixed with Bunter débris, devitrified rhyolite, radiolarian chert, jasper, etc., similar to that found farther west, and a variety of igneous rocks not found in superficial deposits to the west or north. These include purple quartz-felsites, syenite, basalt with and without spheroidal structure, green schist, pink granite, etc. The Cambridge Greensand is found close by at Stanbridge, and has yielded boulders. I found one of basalt on the spoil heaps, which had the appearance of being derived from that deposit.

(*f*) South of Leighton Buzzard,[*] at Grovebury, 300 ft. O.D., much gravel and Boulder Clay lies on the Lower Greensand. In addition to rocks similar to those named in (*e*), the following also were found: Herts conglomerate, green ash similar to that usually associated with devitrified rhyolite. From the mixed character of the material found at (*e*) and (*f*), it may be inferred that they are mainly derived from higher and older deposits.

(*g*) At Wing, west of Leighton Buzzard, and 400 ft. O.D., is a deposit 15 ft. thick, containing much flint and many large sandstone blocks. Rhyolite, Bunter material, and some pieces of pink and greenish gneiss occur also.

(*h*) At Soulby, north-west of Leighton Buzzard, and nearly 400 ft. O.D., is a block of Carboniferous limestone, 4 ft. by 2½ ft. by 3ft.

(*i*) At Brogborough Hill, west of Ridgemount, and over 300 ft. O.D., a large block of basalt occurs.

(*k*) At Moulsoe, about 250 ft. O.D., is a deposit 8 ft. thick, containing much broken flint, quartz, brown quartzites, chalk pebbles, radiolarian chert, etc.

(*l*) Round Hitchin, 269 ft. O.D.,[†] there is a good deal of drift

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[*] *Cf.* "Excursion to Leighton Buzzard," *Proc. Geol. Assoc.*, vol. xv, p. 183. "Excursion to Leighton Buzzard, Wing, and Stewkley," *Proc. Geol. Assoc.*, vol. xvii, p. 139.

[†] *Cf.* W. Hill, "Excursion to Hitchin," *Proc. Geol. Assc.*, vol. xiv, p. 415. C. Reid, "The Palæolithic Implements at Hitchin and their relation to the Glacial Period," *Proc. Roy. Soc.*, 1897, vol. lxi, p. 40. *Cf.* also *Geol. Mag.*, 1897, p. 229.

material, most of the non-local portion of which appears to have been derived from the Chalk slope by means of obsequent streams. Basalt (spheroidal), pink granite, felsites, gneisses, and Carboniferous limestone occur. Flint implements and bones of the large extinct mammalia, etc., have been recorded from these gravels.

(*m*) At Kempston, near Bedford, at above 100 ft. O.D., in one of the upper terrace gravels of the Ouse, similar materials are found, derived from older deposits. Many implements and bones of extinct mammalia, etc., have been found in this and similar deposits round Bedford, etc.[*]

(*n*) At Clay Bush Hill, east of Hitchin, and 329 ft. O.D., deposits containing large basalt boulders and other material, similar to that found at Hitchin, occurs.

Owing to the decrease in the height of the escarpment, long anti-dip streams have been developed, which have carried material from the Chalk slope northward. Mr. A. Jukes-Brown has described the deposits left by some of these streams, now quite disappeared owing to subsequent denudation. The tributary of the Cam, however, which flows northward by Newport, remains, and farther west the Lark and the Little Ouse drain much Chalk country.

Mr. Whitaker[†] has pointed out a peculiar feature with regard to the Boulder Clay of the Cam Valley, where he describes such clay in a buried valley near Newport, Great Chesterford, etc., which is below sea-level. This may be due to earth-movements subsequent to its deposition, as also may the interesting phenomena[‡] described recently by Mr. H. B. Woodward in the same area.

F. 7. Summary.

The study of the area between the Cretaceous and Jurassic escarpments has brought out the following points :

i. That the non-local material found on the north side of the Lower Thames Basin can be traced to this area, or it has come from beyond it, mainly, if not entirely, along two lines of drainage, one of which crosses the Jurassic escarpment at Moreton-in-the-Marsh, and the other extends along the central watershed to the edge of the Trent Basin.

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[*] J. Wyatt, "On Discoveries of Flint Implements and Fossil Mammalia in the Valley of the Ouse," *Quart. Journ. Geol. Soc.*, 1864. J. Wyatt, "On further Discoveries of Flint Implements and Fossil Mammalia in the Valley of the Ouse," *Quart. Journ. Geol. Soc.*, vol. xx, p. 183. "The Flint Implements from the Barnwell Gravels," *Geol. Mag.* (1878), p. 400. T. McKenny Hughes, "The Fauna of the Barnwell Gravels," *Geol. Mag.* (1883), p. 454. T. McKenny Hughes, "On the Correlation of the Pleistocene Gravels in the neighbourhood of Cambridge," *Geol. Mag.* (1888), p. 193. "Excursion to Cambridge," *Proc. Geol. Assoc.*, vol. viii, p. 399. *Cf.* "Nature," vol. xxx, p. 632, and xxxiv, p. 521.

[†] *Cf. Quart. Journ. Geol. Soc.*, vol. xlvi, p. 333, and *Geol. Mag.*, 1895, p. 462 ; see also *B.A Report* for 1904 (Cambridge).

[‡] "On Disturbances in the Chalk near Royston," *Quart. Journ. Geol. Soc.*, vol. lix, p. 362 ; *Cf.* also *Proc. Geol. Assoc.*, vol. xviii, p. 166.

ii. That Lower Greensand Chert, so prevalent in the Lower Thames Basin, does not occur in the superficial deposits of this area.

iii. That the absence of Tertiary flint, pebbles, etc., farther north than the neighbourhood of Buckingham, points to the probable absence of such strata. This would leave the Chalk more exposed to denuding agencies.

iv. That the large majority of the varieties of igneous rocks which occur are mostly found near Lower Cretaceous strata, in which erratic rocks occur. Owing to circumstances the evidence is at present very meagre on this point, but before assigning a more distant origin for these rocks it is necessary to prove they did not come from this source.

v. That the presence of rocks similar to those found near Oxford and in the Moreton Gap in the superficial deposits of the eastern portions of this area, and also in and around the Stevenage Gap, point to a possible former connection between the two gaps.

vi. That to account for the facts observed a large amount of denudation, in all probability accompanied by earth-movements, must have taken place since the earlier gravels were deposited.

vii. That the phenomena observed are in accord with the working hypothesis as stated in the Introduction.

PART IV.

THE COUNTRY NORTH OF THE JURASSIC ESCARPMENT.[*]

Having traced much of the foreign material found in the superficial deposits of the Lower Thames Valley, and parts of East Anglia along two lines of drainage to the Jurassic escarpment at Moreton-on-the-Marsh in the west, and to the high ground near Leicester to the north, it is necessary to complete the inquiry to examine the nature of the superficial deposits in the above-named area. The difficulties are here increased by the possibility that the Chalk escarpment may at one time have been farther west than the present Jurassic escarpment. The presence of flint, chalk, etc., in the superficial deposits north of the Warwickshire Avon and west of the Severn suggest this.

It must, however, be borne in mind that long anti-dip streams, if present, would carry material northward from the escarpment, and therefore the presence of Cretaceous material at a given spot does not *necessarily* prove that the escarpment once existed there.

I have examined the superficial deposits, etc., near Evesham, Shipston-on-the-Stour (an anti-dip stream), Stratford, along the Ridgeway, near Birmingham,[†] Lichfield, Stourbridge, the Clent Hills, Kidderminster, Bridgnorth, Coalbrookdale,[‡] Shrewsbury,

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[*] *Cf.* G. Maw, "On the Drift Deposits of the Severn in the Neighbourhood of Coalbrookdale and Bridgnorth" *Quart. Journ. Geol. Soc.*, vol. xx, p. 130. T. G. Lloyd, "On the Superficial Deposits of Portions of the Avon and Severn Valleys and Adjoining Districts," *Quart. Journ. Geol. Soc.*, vol. xxvi, p. 202. Sir R. J. Murchison's "Silurian System" (not Siluria), chap. xxxvi, etc., p. 509. Sir W. Jardine, "Memoirs of H. E. Strickland," Sir R. J. Murchison, "The Gravel and Alluvia of South Wales and Siluria as distinguished from a Northern Drift covering Lancashire, Cheshire, North Salop, and parts of Worcester," *Proc. Geol. Soc.*, vol ii, p. 230. Prof. W. Sollas, "The Estuaries of the Severn and its Tributaries," *Geol. Mag.* for 1883, p. 374; *Cf.* also *Proc. Geol. Assoc.*, vol. vi, p. 375. E. A. Walford, "The Making of the Dassett and Edge Hills in South Warwickshire," *Proc. Geol. Assoc.*, vol. xiv., p. 185. S. Buckman, "The Development of Rivers, and particularly the Genesis of the Severn," *Nat. Science*, vol. xiv, p. 273; and L. Richardson, "A Handbook to the Geology of Cheltenham and Neighbourhood," Published 1904, chap. vii, p. 177, on Denudation, etc. Rev. W. S. Symonds, "On Some Phenomena connected with the Drifts of the Severn, Avon, Wye, and Usk," *B. A. Report*, 1861, *Trans. of Section*, p. 133; *cf.*, also *Proc. Col. Club*, vol. iii, p. 31, 115. D. Mackintosh, "On the Correlation of the Drift Deposits of the N.W. of England, with those of the Midland and Eastern Counties," *Quart. Journ. Geol. Soc.*, vol. xxxvi, p. 178. H. B. Woodward, "The Chalky Boulder Clay and the Glacial Phenomena of the Western Midland Counties of England," *Geol. Mag.*, 1897, p. 485. A. H. W. Ingram, "On Some Superficial Deposits in the Neighbourhood of Evesham," *Quart. Journ. Geol. Soc.*, vol. xxxv, p. 678. E. Witchell, "Gravels of the Avon Valley, etc.," *Proc. Col. Club.*, vol. iv, pp. 56, 206, 214. H. G. Seeley, "Theoretical Remarks on the Gravels and Drift of the Midlands," *Geol. Mag.*, 1866, p. 495. S. S. Buckman, "Observations of a Cycle Tour," *Proc. Cot. Club*, 1898, p. 217; "Gravel at Moreton-in-the-Marsh" (Gloucestershire), *Quart. Journ. Geol. Soc.*, vol. lv, p. 220; "The Development of Rivers, and particularly the Genesis of the Severn," *Nat. Science*, vol. xiv, p. 273. A. Straham, "On the Origin of the River Systems of South Wales and its Connection with that of the Severn and the Thames," *Quart. Journ. Geol. Soc.*, vol. lviii, p. 207. S. S. Buckman, "River Development," *Geol. Mag.*, 1902, p. 366. W. Hudlestone, Address to Section C., B.A. Meeting at Bristol, 1898; *Cf.* also *Geol. Mag.*, 1898, p. 469.

[†] *Cf.* H. W. Crosskey, "Notes on the Glacial Geology of the Midlands," *Proc. Birm. Phil. Soc.*, vol. xi, p. 169.

[‡] G .Maw, "The Drift Deposits of the Eastern Counties," *Geol. Mag.*, 1867, p. 276 refers to Severn Valley).

Ludlow, Llangollen, the Hope Mountain, Gloppa, above Oswestry,[*] Worcester, the Malverns, the Derbyshire Hills, Kenilworth,[†] between Nottingham and Leicester, around Rugby, etc., in order to see what connection, if any, existed between them as regards their materials and the deposits on the Jurassic and Cretaceous slopes.

In the valley of the Stour much drift occurs, and, as would be expected from the anti-dip direction of the stream, the materials found consist of local Jurassic débris mixed with the same kind of rock fragments as are found at Moreton.

Remains of *Elephas*, etc., are found[‡] in the Stour Valley at Aldermaston, and also farther north at Willoughby and Leamington. The upper portion of the Avon Valley above Rugby has been formed in a somewhat similar manner, and the materials found at Hillmorton[§] and other places near are similar to those found on the high ground north and east.

On crossing the Avon and examining the high ground along the Ridgeway, at 500 ft. O.D., Bunter débris in places, as near Crabb's Cross, 10 ft. thick, is again met with, but while many of the constituents are similar to those found at Moreton, Cumnor, etc., there are several missing which also I have not recognised in any superficial deposit farther north, and it is curious that among those not found are rocks similar to those which occur in the high level gravels of the south-west of England, such as those containing much tourmaline, schorl rock,[||] and the dark chert with secondary quartz veining is rare.

It is therefore possible that a former connection with the south-west formerly existed. It is also remarkable that the devitrified rhyolite and the greenish ash usually accompanying it, which are so prevalent in high level deposits to the south, should also appear to be absent. The further tracing of this interesting igneous rock I must therefore leave for the present.

Malvernian rocks do not appear to have found their way into the higher gravels, but on the west of the Severn at Limbury and other places they occur.

The Rev. P. B. Brodie[¶] describes the drift found to the north-north-west and west of Warwick, at about 400 ft. O.D., and

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[*] *Cf. Midland Naturalist* for 1892, "On the Gloppa deposits." J. Nicolson, "On High Level Glacial Gravels at Gloppa Cyrn-y-bwch, Oswestry," *Quart. Journ. Geol. Soc.*, vol. xlviii, p. 86.

[†] T. Mellard Reade, "On the Southern Drift of England and Wales," *Proc. Liverpool Geol. Soc.*, vol iv, p. 216.

[‡] *History of Willoughby*, published 1828, records Discovery of Mammoth, 1788, and of *Elephas* and *Rhinoceros* in the Jephson Gardens, Leamington.

[§] Rev. P. Brodie, "A Sand Pit at Hillmorton, near Rugby," *Geol. Mag.*, 1892, p. 321. *Cf.* J. W. Wilson, "On the Surface Deposits in the Neighbourhood of Rugby," *Quart. Journ. Geol. Soc.*, vol. xxvi, p 192. E. Clemenshaw, "On the River Gravels of the Avon, etc.," *Report of Nat. His. Soc.*, Rugby School, July 1868; see also the *Report* for 1899, p. 39. "Excursion to Hillmorton and Rugby," *Proc. Geol. Assoc.*, vol. xv, p. 483.

[||] See "On the Occurrence of Pebbles of Schorl Rock from the S.-W. of England in the Drift Deposits of Southern and Eastern England," by A. E. Salter, *Quart. Journ. Geol. Soc.*, vol. lv, p. 220.

[¶] Rev. P. B. Brodie, "On the Drift in a Part of Warwickshire, etc," *Quart. Journ. Geol. Soc.*, vol. xxiii, p. 28.

gives a long list of rocks found which are similar in character to those found at Moreton, and in the Stour Valley. Among others he mentions porphyritic greenstone, which may refer to the rhyolite as it is of a greenish colour and often has large porphyritic crystals. The Bunter Pebble beds crop out immediately to the north, and were no doubt one source of the Bunter débris occurring in the superficial deposits right across England to the North Sea.

The Trappoid breccia of the Clent Hills and the Permian Calcareous conglomerate found between Kidderminster and Bridgnorth do not appear to have contributed to the drifts found within the Jurassic and Cretaceous escarpments.[*]

From the above it is evident that the present Avon system of drainage is of recent origin, and also that that of the Severn must have been greatly modified.

Turning now to the other line of deposits through Central England to the edge of the Trent Basin, we find that a similar thing occurs. The affluents of the Soar and its tributary the Wreak are anti-dip streams draining the escarpment-side of the Jurassic hills of Leicestershire, and bring down some of the materials from the south, which become mixed with débris from older and lower strata. Many large blocks from the Charnwood Forest area occur in places, near Leicester Abbey for instance. As in the case of the Malvernian rocks, they are not found on the Jurassic slope, but in the lower gravels north of the escarpment. Like the gravels, etc., found at lower levels in the Severn and Avon Valleys, those of the Soar and Trent contain many remains of the extinct Pleistocene mammalia,[†] which are not found in the high level gravels of the Jurassic slope. This would indicate a fairly recent excavation of these valleys.

On the north side of the Trent Valley the sources of all the foreign material found in the superficial deposits on the Jurassic slope are situated, the Bunter, near Nottingham, and the Carboniferous strata with its chert and limestone in Derbyshire, while in large hollows 30 ft. deep formed in the Carboniferous limestone, in a similar manner, but on a larger scale, to the pipes in the Chalk, a deposit of unknown age is found over the 1,000 ft. contour near Longcliffe, Newhaven, Minninglow, Caldon Low, etc., largely made up of sand and pebbles.[‡] On comparing these pebbles with those found in a high level in the superficial

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[*] W. Wickham King, "The Permian Conglomerates of the Lower Severn Basin." *Quart Journ. Geol. Soc.*, vol. lv, p. 97.

[†] *Cf. Elephas prim.*, Bos, Rangifer tarandus in Leicester Museum, and also others in the Nottingham Museum. A. Bemrose and R. M. Deeley, "Discovery of Mammalian Remains in the Old River Gravels of the Derwent, near Derby," *Quart. Journ. Geol. Soc.*, vol. lii, p. 497. J. Harrison, "A Sketch of the Geology of Leicestershire and Rutlandshire," Sheffield. W. White.

[‡] G. Maw, "On the Distribution beyond the Tertiary Deposits of White Clays and Sands subjacent to the Boulder Clay Drifts," *Geol. Mag.*, 1867, p. 241. E. Brown, "The Weaver Clays," *Geol. Mag.*, 1867, p. 381. *Geol. Sur. Mem.* for North Derbyshire (1869), p. 127. P. B. Brodie in *Geol. Mag.* 1886, p. 432.

deposits farther south, they are found to be in numerous instances identical in character. Quartz pebbles of various kinds, dark chert without secondary quartz veining, red quartzites partially or wholly bleached, weathered carboniferous chert with crinoids, grits, etc. They are of no great size, and appear to have been derived from the Bunter or Millstone Grit. At Newhaven the deposit is covered with a bed of drift clay containing large boulders of local origin.

Like the Avon, therefore, the Trent is a comparatively recent feature in this area.[*]

The recent discovery of remains of Pliocene mammalia in Derbyshire as described by Prof. W. Boyd Dawkins,[†] is interesting as bearing upon the limit of age of the superficial deposits derived from the north side of the Trent Basin and extending southward to that of the Thames.

In order to account for the position in which these remains were found, he suggests that not less than 330 ft. of Carboniferous limestone has been denuded since their deposition.

There is therefore every probability that the Trent Valley has been formed, and so cut off the supply of materials from Derbyshire, Nottingham, etc., found in more southern superficial deposits, since the Pliocene period.

GENERAL CONCLUSIONS.

The plan adopted in this paper in describing the superficial deposits of central and parts of southern England has been to regard them as the result of the operation of subaerial denuding agencies upon sloping calcareous and other strata. The synclinal basin of the Lower Thames and Kennet has been looked upon as an area which, owing to the action of fluviatile and possibly other agencies, has been the receptacle or depository of the often far-travelled hard portions of distant strata. It has been shown that around this area are a series of gaps through which this non-local material has come, and that the superficial deposits in the vicinity of the gaps form "Drift Series" capable of comparison with each other.

The materials composing the superficial deposits on the south side of the Lower Thames Basin were found to be either of local derivation or to have come from the south. On the north side, however, both northern and southern material occur. From evidence obtained at the gaps, it appears that denudation has operated there through at least 400 ft., since the highest gravels are about that height above existing streams. From about 200 ft. to 150 ft. below these the constant occurrence of large blocks not

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[*] H. C. Sorby, "Notes on the Excavation of the Valleys in Derbyshire," *Geol. Mag.*, 1869, p. 347.

[†] Prof. W. Boyd Dawkins, "On a Pliocene Ossiferous Cavern at Dove Holes," *Quart Journ. Geol. Soc.*, vol. lix, p. 105.

in situ points to greater intensity on the part of the denuding agencies, while about 150 ft. above existing streams palæontological evidence in the shape of remains of the extinct Pleistocene mammalia and of Palæolithic implements begin to appear.

Although now the Goring Gap is the only water communication with the area to the north of the escarpment, yet evidence was brought forward to show the former existence of others near Stevenage and Bishop's Stortford. The materials forming the superficial deposits on the northern side of the Lower Thames Basin, taken as a whole, show that in the oldest and highest drifts local material mixed with débris from Palæozoic rocks occurs, a little lower rocks derived from the Trias come in and become very plentiful, later and lower deposits contain in addition débris from Jurassic strata. This favours the idea that as the Chalk escarpment receded, rocks in that order were exposed to denudation, and is just the succession demanded by the hypothesis stated in the Introduction.

Lying between the northern and southern slopes of the Lower Thames Basin is a series of superficial deposits remarkable for the abundance of southern material they contain, leading us to the conclusion that the southern slope was formerly more extensive than at present, and suggesting the probability of earth-movements since their deposition. The acceptance of this inference makes the former history of the superficial deposits of Herts and East Anglia more clear, and shows in what direction the Bunter and other material found its way *viâ* the Goring and Stevenage Gaps, across in a more or less west to east direction to the North Sea. Its acceptance also forces us to regard the present Lower Thames Valley as of recent geological date.

In treating of the area between the Cretaceous and Jurassic escarpments it was shown that the non-local material found on the north side of the Lower Thames Basin came across that area along two main lines. It was also shown that the presence of Bunter débris in deposits consisting chiefly of Jurassic material between Woodstock, Buckingham and the Stevenage Gap, showed the possibility of there being at one time fluviatile connection between the Moreton and Stevenage Gaps. The difficulties connected with correlating deposits in this area will be seen when it is stated :

i. That, according to the suggested hypothesis, materials were first transferred across to the Chalk slope on the north of the Lower Thames Basin over strata now denuded away.

ii. That anti-dip or obsequent streams as the escarpment receded, carried some material northward again.

iii. That the longitudinal valley system of the Ouse has been initiated, causing a further easterly or north-easterly transference of material.

iv. That the denuded Lower Cretaceous strata in that area itself may have contained foreign material, which was added to that previously present.

v. That in all probability earth-movements have further complicated matters.

In the country north of the Jurassic escarpment, it was shown that most of the material derived from the north, occurred *in situ*. It is thus shown that the hypothesis suggested is capable of explaining the phenomena observed.

In the course of the main inquiry some subsidiary questions have arisen on the most important of which a few remarks may well be made here.

1. *The Age of the Deposits Described.*—It has been shown that up to about 150 ft. above the present streams the superficial deposits yield evidence of their being of Pleistocene Age. Above that no evidence is at present forthcoming until deposits are reached which are in all probability older than any of those herein described. These include the Lenham deposits of Lower Pliocene Age, and the deposits containing Pliocene mammalia at Dove Holes, in Derbyshire. This points to an extreme downward limit, and is supported by the fact that in East Anglia the oldest set of gravels rests directly on Crag deposits.

2. *Earth-movements.*[*]—The probability of earth-movements having affected the superficial deposits has been referred to several times in the preceding pages. The presence of Lower Greensand Chert from the Wealden area as far as the northern slope, and for some distance into East Anglia as far as the line of deposits which are found from Goring Gap at 650 ft. O.D. to the coast at Dunwich, shows that the original valley between the high ground of the Midlands and that of the Wealden area ran in a more or less south-west to north-east direction. The next set of deposits, consisting mainly of Bunter material, took a rather more southerly course, roughly parallel to the preceding, while the present valley runs from west to east. This may be due to denudation only, but it appears to me to be far more feasible to suppose that the synclinal trough between the two tracts of higher ground has undergone modification. The steep descent of the Boulder Clay deposits, and their great height on the escarpment, point to such a modification having taken place

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[*] S. V. Wood, Jun., "Further Remarks on the Origin of the Valley System of the S.-E. Half of England, Prompted by the Result of a Boring near Witham, Essex," *Geol. Mag.*, 1881, p. 502. W. H. Dalton, "Undulations of the Chalk of Essex," *Essex Nat.*, vol. v, p. 113. W. H. Dalton, "The Blackwater Valley, Essex," *Trans. Epping Forest Club*, vol. ii, p. 15. Sir A. Geikie, "On Tertiary Plateaux in N.W. Europe," in which considerable movement since Tertiary times is advocated. Sir J. Prestwich states that the tilting of the Westleton Shingle immediately preceded the Glacial deposits. *Cf.* W. Topley in his "Survey Memoir of the Weald," p. 285, and *Proc. Geol. Assoc.*, vol. xiv, p. 121 (section). W. H. Dalton, "On the Formation of the River and Other Valleys in the East of England," *Trans. Epping Forest Field Club*, vol. ii, p. 15. S. V. Wood, Jun., "On the Formation of the River and other Valleys in the East of England," *Phil. Mag.*, ser. 4, vol. xxvii, p. 180; also *Trans. Epping Forest Field Club*, vol. iv. *Cf.* Prof. G. A. J. Cole, *Knowledge*, vol. xxiii, p. 89.

subsequently to the deposition of the higher gravels containing only Palæozoic and Triassic non-local material. The phenomena observed between Hitchin and Barkway, and described recently by Mr. H. B. Woodward, F.R.S., to my mind support this idea.*

3. *Climatic Changes.*—Excluding the "Boulder Clay," with which this paper only incidentally deals, there is but little decisive evidence on this point, except that given by the Pleistocene mammalia up to 150 ft. O.D. Between 200 ft. and 250 ft. above present streams large boulders are more common than at other heights, and may point to severer conditions during that period of excavation.

4. *Marine Action.*—In the deposits themselves no sign of marine action has, to my mind, been detected, except, perhaps, in the gravels overlying the Crag at Dunwich and Westleton, but the indirect action of the gradual approach of the sea is apparent, and has brought about a kind of pseudo-elevation. The east coast at the present day is a standing example of the power of marine erosion. If this has been going on for some time, the sea, by continually cutting back the shore line, would cause the "base line of erosion" of all streams flowing into it to be gradually pushed back in the direction of the source, leading to a deepening of their valleys, and, as a natural consequence, leaving superficial fluviatile deposits at varying heights, which, owing to their pervious character, are able to resist denudation. In this way the height of deposits like those at Coombe Warren, Crayford, Milton Street, near Northfleet, where a fluviatile fauna has been found 90 ft. above the Thames, can be explained.†

To adequately illustrate the remarks made in this paper, a large scale relief model, showing the "Solid" geological strata, as well as the superficial deposits, is necessary. This being at present out of the question, I must refer my readers who wish to continue this subject, to the new Ordnance Survey 1-in. scale coloured maps in which the contours are plainly seen. Bartholomew's coloured contour maps, scale two miles to the inch, are also very useful.

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* "On Disturbances in the Chalk near Royston," *Quart. Journ. Geol. Soc.*, vol. lix, p. 362. *Cf.* also *Proc. Geol. Assoc.*, vol. xviii, p. 166.

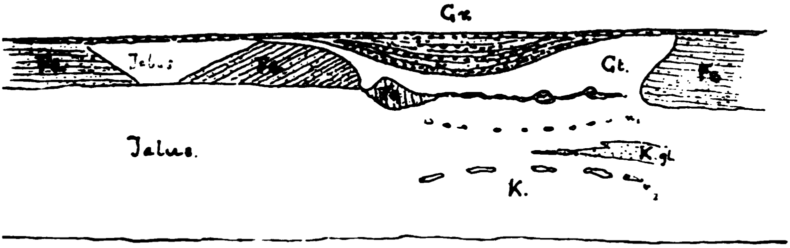
† *Cf.* F. C. G. Spurrell in *Proc. Geol. Assoc.*, vol. xi, p. 72, and p. 210 *et seq*

EXCURSION TO CUMNOR.

SATURDAY, JUNE 25TH, 1904.

Directors: PROF. SOLLAS, M.A., F.R.S., AND MISS HEALEY.
Excursion Secretary: H. WALKER, A.R.C.Sc., F G.S.

THE party from London arrived at Oxford shortly after 3 p.m., and were met by some thirty members of the Ashmolean Natural History Society of Oxfordshire. Most unfortunately Prof. Sollas was prevented by family reasons from being present to act as director. The party proceeded at once to walk, by way of Ferry Hincksey to Cumnor Hurst, where the following section was seen:



Gr. Fluvio-glacial gravel.
Gt. Clay, probably gault.
Fe. Iron Sands (cretaceous).
K. Kimmeridge Clay.
Kgl. Glauconitic sandy layer in Kimmeridge Clay.
n 1 Small nodules in Kimmeridge Clay.
n 2 Large septaria in Kimmeridge Clay.

DIAGRAMMATIC SECTION, CHAWLEY WORKS BRICK PIT, 1904.
W. J. Sollas.

The fluvio-glacial gravels, which are generally but thinly strewn over the summit of the hill at a height of 520 feet, also fill a long trough excavated in a clay which has yielded fragments of *Hoplites interruptus* and must therefore be Gault. It also contains phosphatic nodules.

This clay fills hollows in the Ironsands which are unfossiliferous, but present some interesting dislocations simulating faults. The Kimmeridge Clay immediately underlies the Ironsands, without any intervening Portland. It yields the usual fossils, *Thracia depressa* and *Proctocardia striatula* being fairly common.

The party then proceeded to the village of Cumnor for tea, after which some returned to the pit and others found their way direct to Oxford.

REFERENCE.

1887. BATHER, F. A.—"Note on the Geology of Cumnor Hurst." *Journal of the Oxford Univ. Jun. Sci. Club*, vol. i, pp. 30-32.

ORDINARY MEETING.

FRIDAY, NOVEMBER 4TH, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: R. D. Oldham, F.G.S., Cecil John Varicas.

The meeting then resolved into a Conversazione, and the following is a list of the exhibitors and their exhibits:

THE DIRECTOR GENERAL OF THE GEOLOGICAL SURVEY: Geological model of the Isle of Purbeck, Dorset. Recently published Geological Maps and Memoirs.

MISS CAROLINE BIRLEY: Gasteropoda from the Pliocene Beds (Plaisancian) of Bordighera, Italy.

REV. J. F. BLAKE, M.A., F.G.S.: Specimens of Schistose Breccia from the Isle of Man, and fossils from Boulders in the drift of Barningham, Suffolk.

G. F. BROWN: Chalk fossils from Burwell, Norwich and Grays.

BRYAN CORCORAN: Samples of French Burr used for building into Millstones from the neighbourhood of Vienne. Stone flakes found with beans imported from Egypt.

ROBERT ELLIOTT: Flint Implements from Swanscombe and Galley Hill.

G. E. DIBLEY, F.G.S.: Jaw of *Mosasaurus* from the Chalk of Cuxton (zone of *Holaster planus*). Recently described Pectens and Limas from the Chalk.

JAMES FRANCIS: Devonian fossils from the Ardennes, the Eifel, and Brittany, and fossils from the Middle and Lower Lias of Dorsetshire.

W. H. GRIFFIN (per G. E. Dibley): Specimens of recent ferruginous sand from the summit of Shooter's Hill, Kent.

W. F. GWINNELL, B.Sc., F.G.S.: A series of folded and contorted gneisses, schists and slates from the Western Highlands, Ireland and Norway. Reptilian remains (*Iguanodon*, *Ichthyosaurus*, *Plesiosaurus*, and *Pterodactylus*). A fine Labyrinthodont jaw of *Loxomma* from the Lower Carboniferous of Midlothian. A series of bones of the Dodo of Mauritius; and a tarso-metatarsal bone of the giant Moa of New Zealand (*Dinornis maximus*).

R. S. HERRIES, M.A., SEC. G.S. and HENRY PRESTON, F.G.S.: Fossils from the Kimmeridge (or Oxford) Clay, Woodhall Spa, Lincs.

G. J. HINDE, PH.D., F.R.S.: Fossils from the Marsupites Chalk of Beddington.

A. J. HOGG: Implements from the Wandle Gravel at Mitcham. Photographs of typical forms of tools of the Stone Age.

T. V. HOLMES, F.G.S.: Plan of the Chislehurst Caves drawn to scale by Mr. T. E. Forster, Mining Engineer, of Newcastle-on-Tyne.

MISS M S. JOHNSTON: Triphyline and other minerals from Bavaria, etc.

A. S. KENNARD: A series of skulls of Roman and Mediæval Sheep.

JAMES LOVE, F.G.S.: Photographs and other pictures illustrating Scotch scenery.

E. T. NEWTON, F.R.S., F.G.S.: Fossils from the Bembridge Marl, Foreland Point, Bembridge, Isle of Wight; and fossils from the Silurian rocks of the Ludlow District.

JAMES PARKER, M.A., F.G.S.: Specimen of *Lusus naturæ* from the Longmyndian rocks of Cardingmill Valley near Church Stretton.

B. C. POLKINGHORNE, B.SC., AND WILLIAM WRIGHT: Tests and Plates of *Marsupites* from Russell Hill near Purley, and a specimen of *Synhelia sharpeana* from Leatherhead.

HENRY PRESTON, F.G.S.: Early British Pottery from the Ironstone workings near Grantham.

A. E. SALTER, D.Sc., F.G.S.: A stag's horn chalk pick from Ware, and a series of erratic Igneous rocks obtained during the excursions of 1904.

E. W. SKEATS, D.Sc., F.G.S.: Barton Clay fossils from the Hampshire coast, and fossils from the Ludlow district.

J. THRUSSELL: A series of photographs of the Andes, reproduced by the Buenos Ayres and Pacific Railway Company.

LL. TREACHER, F.G.S.: Cast in flint of *Ammonites leptophyllus* from the G.W.R. cutting, Waltham, near Twyford. Varieties of *Echinocorys* from the Upper Chalk of Berkshire, Buckinghamshire, and Hampshire. *Galerites* from the Upper Chalk of Buckinghamshire. Bryozoa from the Upper Chalk.

LIEUT.-COL. UNDERWOOD: A curiously-shaped flint

H. J. OSBORNE WHITE, F.G.S.; Test of *Marsupites testudinarius* with brachial ossicles, and a group of plates of Uintacrinus from Kintbury, Berks. Brachial ossicles of a small crinoid from the *M. cor-anguinum* zone, Turville, Oxon. Block of Ferruginous Conglomerate from Pebble Gravel, Russell Water, Oxon.

ORDINARY MEETING.

FRIDAY, DECEMBER 2ND, 1904.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: Cyril E. N. Bromehead, Maurice Deacon, F.G.S., R. Pierce Gould, J. F. N. Green, Herbert L. Hawkins, Maurice Leriche, Theodore Parkinson, Richard Lee Roberts, Arthur Vaughan, D.Sc., F.G.S., Mark Wilks, Mrs. Maud Woodward, William Wright.

A paper on "The Superficial Deposits of Central and parts of Southern England," was then read by Dr. A. E. Salter.

ORDINARY MEETING.

FRIDAY, JANUARY 6TH, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

Miss Sybil Thursby was elected a member of the Association.

Dr. C. Gilbert Cullis then exhibited and explained by means of the lantern a number of beautiful photographs comprising the third series issued to subscribers by the British Association Geological Photographs Committee.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 3RD, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

Messrs. S. N. Glass and H. M. Kruszinski were appointed Scrutineers of the ballot.

The following report of the Council for the year 1904 was then read:

THE numerical strength of the Association on December 31st, 1904, was as follows:

Honorary Members	15
Ordinary Members—	
a. Life Members (compounded)	165
b. Old Country Members (5s. Annual Subscription)	2
c. Other Members (10s. Annual Subscription) .	409
Total	591

This shows an increase of three, as compared with the corresponding figures for the previous year.

During the year forty new members were elected.

The Council regret that the Association has lost five members by death: Lieut.-General C. A. McMahon, W. R. Melhuish, Septimus P. Moore, Charles Pearce Serocold, and John Spink.

Lieut.-General Charles Alexander McMahon died on the 21st February last at the age of 74 after an eventful career, not only as a geologist and petrologist, but also as an army officer. He served for eight years in the 39th Madras Native Infantry and for 30 years on the Punjab Commission. He was late Commissioner of Lahore and a Fellow of Lahore University. His name will be remembered in India for his 30 years of excellent work as a Commissioner and Civil Judge. He was an ardent and able geologist, and was a pioneer in the exploration of the principal rock groups of the Western Himalayas. The so-called Himalayan Central Gneiss he showed to be an intrusive granitic formation. After his retirement he continued his researches with enthusiasm, devoting special attention to petrological and mineralogical investigations. He became a member of the Association in 1887, and occupied the Presidential chair during 1894-5. He summarised the chief results of his work in his two

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1904. Cr.

	£	s.	d.		£	s.	d.
To Balance from 1903	122	6	3	By Printing "Proceedings"	121	0	2
" Life Compositions	20	5	0	" " Monthly Circulars	22	11	9
" Admission Fees	20	0	0	" Miscellaneous Printing...	20	17	6
" Annual Subscriptions	180	16	6	" Illustrating "Proceedings" and Circulars ...	49	6	5
" Dividends on Nottingham Corporation Stock...	31	12	0	" Postage, Telegrams and Messages	38	17	6
" Sale of Publications	14	7	6	" Addressing	6	18	0
				" Library	2	10	10
				" Attendance, Lighting, Lantern, etc., at Evening Meetings	18	4	6
				" Excursions	13	4	6
				" Insurance...	2	15	0
				" Stationery	1	17	5
				" Miscellaneous Expenses	0	14	3
				" Balance at Bank of England, Dec. 31st, 1904...	90	9	5
	£389	7	3		£389	7	3

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £1,108 14s. 5d. Nottingham Corporation Stock.

January 17th, 1905.

HENRY A. ALLEN, } *Auditors.*
W. P. D. STEBBING, }

sidential addresses to the Association, and several other im-
tant papers from his pen have appeared in the PROCEEDINGS.

The financial position of the Association continues fairly
isfactory. The income in 1904 was £267 1s. 0d., as compared
h £263 2s. 4d. in the previous year. There was a decrease
£3 19s. 6d. in annual subscriptions but, on the other hand,
re was an increase of £7 10s. in admission fees. The expendi-
e for the year was £298 17s. 10d., being £59 16s. 8d.
ater than the expenditure for 1903 and £31 16s. 10d. in
ess of the actual income for 1904. The abnormally heavy
penditure was due to the publication of another instalment of
Rowe's work on the Chalk, and the Council have been
abled to spend beyond their ordinary income in the production
this important work only by the grant of £50 made by the
yal Society in 1901 in aid of the publication of these papers.
at grant has now been exhausted. The comparatively heavy
penditure of the year made it impossible for the Council to in-
st the sum of £40, as proposed in the last Report, so that the
vested capital of the Association remains as before.

The PROCEEDINGS for the year have been issued in six parts,
hich, with one double number, make up the ten parts
mpleting Vol. XVIII.

The parts for this year comprise 299 pages, forty-two plates,
cluding one map in colours, and thirty-six figures in the text.

Parts one and four were wholly devoted to Dr. Rowe's papers
n the Zone of the White Chalk.

The thanks of the Association are due to the several authors
r their communications, and also to the Council of the
eological Society and the Council of the Cotteswold Field Club
r kindly granting the use of certain clichés employed for
lustration.

The report of one of the excursions was not received in time
be included in the volume.

During the past year the work of arranging the library has
een begun; sufficient shelves have now been provided by the
ollege to display all the books likely to be in demand, and they
ave been arranged with regard to easy accessibility of the more
seful English and foreign publications rather than under any
efinite scheme of classification.

The bound and unbound sets, which were formerly kept apart,
re now arranged continuously in geographical groups.

Considerable arrears of binding have been allowed to accumu-
ate of late years and a grant of £30 would be needed to over-
ake arrears and bind the important serials up to date. Many
umbers are found to be missing and must be procured before
inding can be completed. In many cases perhaps exchanges
ould be effected with Societies whose series of the PROCEEDINGS
f this Association are incomplete.

It is hoped that the work of binding and rearranging may b completed by the summer.

The additions to the Library are chiefly in the form of volume and parts of works published serially and obtained in exchange.

Mention may, however, be made of donations of the Ge logical Survey Memoirs and colour-printed one-inch maps, the chi memoirs received are "On the Oolitic and Cretaceous Roc South of Scarborough," "On the Country round Belfast," "On t Tertiary Igneous Rocks of Skye," and the 3rd vol. of "T Cretaceous Rocks of England."

The following is a list of the papers read at the even meetings:

"The Jurassic Rocks of East Greenland," by Miss ETHEL G. SKEAT.

"On Some Examples of the Different Types of Geological Formatio with Special Reference to Recent Excursions of the Association (Estuari Marine and Lagoon Deposits)," being the Address of the retiring Presiden H. W. MONCKTON, F.L.S., F.G.S.

"The Geology and Fossils of the Ludlow District," by THE PRESIDEN with supplementary notes by E. S. COBBOLD, F.G.S., G. J. HINDE, Ph.D F.G.S., Miss E. M. R. WOOD, M.Sc., Rev. J. F. BLAKE, M.A., F.G.S S. S. BUCKMAN, F.G.S., E. A. NEWELL ARBER, M.A., F.G.S., an F. RAW, B.Sc, F.G.S.

"The Superficial Deposits of Central and Parts of Southern England,' by A. E. SALTER, D.Sc., F.G.S.

Lectures were delivered by C. GILBERT CULLIS, D.Sc., F.G.S., on "Th British Association Geological Photographs"; by GEORGE BARROW, F.G.S. on "The Metamorphism of Sediments"; by H. ARNOLD BEMROSE M A., F.G.S., on "The Geology of Buxton"; and by W. J. LEWIS ABBOTT F.G.S., on "The Geology and Prehistoric Anthropology of the Hasting District."

The thanks of the Association are due to all of these.

The usual Conversazione was held in November, and a ful list of the exhibits will be found in the PROCEEDINGS. Thank are due to the many members who contributed to the success o that evening.

During the season of 1904 rain interfered with the success o one or two excursions, but to a less extent than in the season c 1903.

Arrangements were made for one museum visit, seven half-da excursions, six whole-day excursions, and the customary mor extended excursions at Easter, Whitsuntide, and the Lon Excursion.

The following is a list of the dates, localities, and directors:

DATE.	PLACE.	DIRECTORS.
March 5	Haddenham (Bucks)	A. Morley Davies, B.S F.G.S.
March 12	Croydon Bourne	W. Whitaker, F.R.S.
March 19	British Museum (Natural History) Palæobotanical Collections	E. A. Newell Arb M.A., F.L.S.

DATE.	PLACE.	DIRECTORS.
April 1 to 5 (Easter)	Vale of Evesham and the Northern Cotteswolds	C. Callaway, M.A., D.Sc., F.G.S., and L. Richardson, F.G.S.
April 23	Farnham	H. W. Monckton, F.G.S., and H. A. Mangles, F.G.S.
April 30	Hayes and the Dawley Gravel Pits	H. W. Monckton, F.G.S., and R. F. de Salis, F.G.S.
May 7	Henley-on-Thames	H. J. Osborne White, F.G.S.
May 20 to 25 (Whitsuntide)	Buxton and North Derbyshire.	H. Arnold Bemrose, M.A., F.G.S., Prof. W. Boyd Dawkins, M.A., D.Sc., H. H. Hubbersty, and H. Lapworth.
June 4	Cuxton	F. J. Bennett, F.G.S.
June 11	Hastings	W. J. Lewis Abbott, F.G.S.
June 18	Chilworth, Blackheath, and Pitch Hill	R. S. Herries, M.A., F.G.S.
June 25	Cumnor	Prof. W. J. Sollas, D.Sc., M.A., F.R.S., and Miss Maud Healey.
July 2	Holborough and Burham	G. E. Dibley, F.G.S.
July 9	Chichester and Selsey	J. V. Elsden, B.Sc., F.G.S., and W. Whitaker, F.R.S.
July 16	Upminster, Great Warley, and Brentwood	H. B. Woodward, F.R.S.
August 3 to 9 (Long Excursion)	The Ludlow District	The President, W. H. Banks, M.A., E. S. Cobbold, F.G.S., Charles Fortey, John Hopkinson, F.G.S., Frederick King, Rev. W. M. D. La Touche, B.A., C. Davies Sherborn, F.G.S., and Miss F. M. R. Wood, M.Sc.

Detailed reports of these excursions will be found in the PROCEEDINGS.

On three of the Excursions the issue of cheap tickets to the members resulted in a monetary loss to the Association, the total loss amounting to £1 6s. 3d.

Generally, however, the excursions were well attended, and on the excursions to the Croydon Bourne and to Hastings the attendance at each, including visitors, exceeded seventy.

The Excursion Secretaries responsible for the conduct of the excursions during the year have been :—Miss Foley, Dr. C. G. Cullis, and Messrs. G. E. Dibley, J. V. Elsden, R. Herries, H. Kidner, H. Walker, A. Williams, and G. W. Young.

Thanks are due to the Directors of the Excursions, and also to the following for asssistance and hospitality : Mr. W. H.

Haydon, at Haddenham; Mr. H. A. Mangles, at Farnham; Lieut. G. E. Coke and Mr. E. Sandeman, engineer, of the Derwent Valley Works in Derbyshire; Rev. Canon Toone, at Cuxton; Mr. C. Dawson, Mr. Alderman Tuppeny, J.P., and Mr. John Lewis, C.E., Hastings; Miss Spottiswoode, at Chilworth; Mrs. King, Mrs. La Touche, Professor W. W. Watts, the Mayor and Corporation of Ludlow, the Clee Hill Dhu Stone Co., the Clee Hill Granite Co., Mr. R. L. Roberts, the Ludlow Natural History Society, the Dolyhill Stone Co. and Mr. W. Clarke, at Ludlow.

Thanks are due to the Council of University College for the facilities they continue to offer the Association in the use of rooms for their meetings.

There are several changes in the House List. Mr. W. Whitaker retires from the Vice-Presidency and from the Council; Mr. Henry Fleck and Miss M. C. Foley retire from the Council. Mr. J. Allen Howe retires from the Editorship of the PROCEEDINGS, and the thanks of the Association are due to him for the time and care that he has devoted to the duties of Editor during the past two years. Dr. E. W. Skeats, having received an appointment as Professor of Geology at the University of Melbourne, is obliged to relinquish the duties of Excursion Secretary, and the Council feel sure that he leaves England with the thanks of the members for his services in the past, and with good wishes for his success in the future.

The names of those suggested by the Council to fill the vacant offices will be found on the ballot paper.

On the motion of Mr. J. V. Elsden, seconded by Mr. A. S. Kennard, the Report was adopted as the Annual Report of the Association.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:

PRESIDENT:

A. Smith Woodward, LL.D., F.L.S., F.G.S.

VICE-PRESIDENTS:

Rev. J. F. Blake, M.A., F.G.S.
R. S. Herries, M.A., V.P.G.S.
H. W. Monckton, F.L.S., F.G.S.
Capt. A. W. Stiffe, F.G.S.

TREASURER:

R. Holland.

SECRETARIES:

Percy Emary, F.G.S.
A. C. Young, F.C.S.

EDITOR:

A. E. Salter, D.Sc., F.G.S.

LIBRARIAN:

Prof. E. J. Garwood, M.A., F.G.S.

Twelve other Members of Council :

H. A. Allen, F.G.S.
C. W. Andrews, D.Sc., F.G.S.
L. L. Belinfante, M.Sc., B. ès L.
C. Gilbert Cullis, D.Sc., F.G.S.
G. E. Dibley, F.G.S.
John S. Flett, M.A., M.B., D.Sc., F.G.S.
Upfield Green, F.G.S.
Miss M. Healey.
J. Allen Howe, B.Sc., F.G.S.
F. L. Kitchin, M.A., Ph.D., F.G.S.
Miss E. Pearse, B.Sc.
Arthur W. Rowe, M.B., M.S., M.R.C.S., F.G.S.

The best thanks of the Association were then voted to the Officers and Members of Council retiring from office, to the Auditors, and to the Scrutineers.

The President then delivered the Annual Address, entitled, "Modern Methods in the study of Fossils."

On the motion of the Rev. J. F. Blake, seconded by Mr. W. Whitaker, it was unanimously resolved that the President's Address be printed in full.

This terminated the Annual Meeting.

ORDINARY MEETING.

Friday, February 3rd, 1905.

A. Smith Woodward, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association :

John Chambers, Raymond Horace Chandler, John Russell Larkby, Arthur Leonard Leach, Henry Stuart Beville Whitley.

There being no further business, the meeting then terminated.

ORDINARY MEETING.

Friday, March 3rd, 1905.

A. Smith Woodward, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association:

James Cross, W. G. Freeman, B.Sc., F.L.S., Richard M. Hugo, M.D., Griffith Humphreys, Frank Morey.

A lecture was then delivered by Prof. H. A. Miers, M.A., F.R.S., on "The Diamond Mines of South Africa," and was illustrated by lantern slides.

ORDINARY MEETING.

FRIDAY, APRIL 7TH, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The President referred in sympathetic terms to the loss sustained by the Association in the death of one of its founders, Mr. Jeremiah Slade.

The following were elected members of the Association:

John Barrow, George S. Blake, Thomas Crook, Ralph Freeman, Bernard R. Jones, Sydney M. Owen, Henry C. Sargent, Miss Ida L. Slater.

The following paper was then read:—"On the Relative Ages of the Stone Implements of the Lower Thames Valley," by Martin A. C. Hinton and A. S. Kennard.

MODERN METHODS IN THE STUDY OF FOSSILS.

By A. SMITH WOODWARD, LL.D., F.R.S.

(Presidential Address delivered February 3rd, 1905.)

ONE of the most conspicuous features of the Geologists' Association has always been the catholicity of its interests. From the speculations of the Nebular Hypothesis to the phenomena of earthquakes and volcanoes; from the study of deep-sea dredgings to that of metamorphic rocks; from the optical properties of a crystal to the evolution of a mammal or even of man himself—all subjects of scientific inquiry have fallen within the scope of our proceedings. This wide sympathy with the progress of the natural sciences has, indeed, been one of the main factors in the continual success of the Association. The majority of our members are well occupied with other vocations besides the pursuit of pure science, and have only the hours of recreation to devote to geological studies. The wider the scope and the more general the nature of the questions discussed at our meetings, the more thoroughly, therefore, are they appreciated.

When the Association was founded, nearly half a century ago, it was much easier to deal with the latest results of geological research in general terms than it is in these later days of extreme specialisation. In fact, the opinion has sometimes been expressed, that it is no longer possible for the amateur, with restricted leisure, to do much towards the progress of scientific discovery. I venture to think, however, that, so far as the past history of the earth is concerned, there is still ample scope for casual work of the highest value. The collector of fossils, in any case, even if he be confined to one small district, is just as important now as he ever was for the progress of Palæontology. The only difference is that, whereas in former days his chief interest centred in filling a cabinet with choice specimens, his present aim should be rather to illustrate certain definite problems and principles which modern research has formulated. At the time when Parkinson's "Organic Remains" was a drawing-room book, and when Mantell could secure no less than 130 personal subscribers for his "Geology of the South-east of England," fossils excited interest as objects of curious wonder; in later days they have gradually become familiar even to the uninitiated, and the pleasure experienced in collecting them depends on their connection with certain theories of life and change which have a bearing on some of the most fundamental problems of Natural Philosophy.

It is true that in some respects the study of fossils has gradually been beset with repellent difficulties, which it is not always easy to ignore. There are, indeed, three circumstances which seriously hinder a beginner, and are detrimental to the progress even of an expert student.

In the first place, the advances made by research have led to the discovery of many mistakes in the original naming of genera and species on the evidence of imperfect specimens; while they have also proved that in some cases different parts of one and the same animal or plant have received two or more distinct names. All these corrections have to be remembered when consulting the books and papers which deal with the fossils in question. It is thus necessary to be familiar with the entire history of their discovery.

Secondly, the so-called "law of priority" in nomenclature has caused too many mere literary critics to invade scientific journalism with long disquisitions on matters concerning which they are incompetent to form a judgment; while, still worse, the glamour of easily-earned glory which the aforesaid "law" promises to an industrious reader, has diverted from scientific work not a few talents which began well and might have done real service in the advancement of research. It still has to be recognised that generic and specific names (which are simply instruments for convenience) evolve to an exact meaning just as organisms evolve to produce fixity in their parts in a favourable environment. It also has to be generally realised that the only nomenclature of genuine use is that actually employed in scientific memoirs, and not that of mere lists which are prepared as literary exercises. The result is, that since the fatuous fad of retrospective "priority" became fashionable, the naming of certain groups of fossils has lapsed into inextricable confusion; and until common-sense methods prevail a serious obstacle is opposed to real scientific work.*

Finally, it must be admitted that most of the books which a beginner has to consult are too much in the nature of dictionaries, and give too little prominence to the statement of problems and general principles. The accumulation of endless new facts, is, of course, essential to all progress; but the only sensible advances in science are made when known facts are correlated in the light of new discoveries. In the present state of Palæontology, I am only acquainted with one general elementary treatise which deals with the whole subject and is helpful from this point of view. I refer to Prof. H. S. Williams's little work on "Geological Biology," published in New York in 1895 (Henry Holt & Co.), which seems to be scarcely known among students in this country.

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* For an illustration of the impossibility of applying the "law of priority" to Conchology, see A. J. Jukes-Browne, "On some Questions of Nomenclature," *Journ* *Conchology*, vol. ii (1904), pp. 97-103.

For much service to Palæontology, however, deep reading is far from essential, and no casual contributors are doing more valuable work than those who let it be known in their own neighbourhood that they are interested in fossils. Their houses become the receiving offices, so to speak, to which all accidental discoveries are brought; and they are thus the means of preserving from destruction many unique specimens which would otherwise be lost. Only quite lately the finest Labyrinthodont skull hitherto discovered in Britain—one of the most important Triassic skulls ever found—was rescued solely because the Stanton quarrymen knew that the Rev. F. F. Key was interested in fossils and might be glad to see "a calf's head in stone" (as they described it) before it was broken up. In fact, a large proportion of the known extinct animals are only represented by one or two specimens obtained in this accidental manner; and when we remember how sporadic is the distribution of fossils in many rocks, we can appreciate the importance of spreading over the kingdom a body of amateurs such as those who form the greater part of our Association.

In this connection I also wish to emphasise the scientific value of collections of mammal-bones carefully made from superficial deposits, especially from those of known historic date. In our country very little attention has hitherto been devoted to the domestic animals which accompanied man at different times during the many centuries which have elapsed since history began in this part of Europe. Two of our members, Dr. Frank Corner and Mr. A. Santer Kennard, have already made much progress in obtaining materials for such a study from the neighbourhood of London; and some of us remember the interesting series of skulls of sheep, of various known dates, exhibited by Mr. Kennard at our last Conversazione. We need large collections of bones from all the old centres of population; for when they are sufficiently extensive they will prove interesting not only from our point of view, but also from that of the historian who is dealing with trade routes and migrations.

The collector of fossils greatly enhances the value of his contributions to Palæontology as soon as he begins to devise methods of preparing them for satisfactory study. Some of our most striking modern advances, indeed, have only been made possible by improvements in the art of extracting fossils from the matrix. It is long since Mantell began pioneer work of this kind and astonished the audiences at his lectures with the fossil fishes which he had laboriously divested of enveloping chalk by means of small knives and needles. It is also long since he pieced together and chiselled out the bones of Dinosaurs from the Wealden Sandstone and Kentish Rag. The methods he adopted have been successfully employed by many subsequent workers, until now we have reached the refinement of cleaning fossils by machinery. Some years ago Mr. B. Stürtz, of Bonn, and Dr C. E. Beecher, of New Haven, devised a means of treatin pyritised fossils in hard rock with metal brushes, and achieve remarkable success in cleaning the most minute structures o starfishes and trilobites. Our member, Mr. Upfield Green, ha done well in applying the same method to pyritised fossils fro the Devonian slates of Cornwall. Another member, Dr. Arthu W. Rowe, has advanced a step further in using not only meta brushes but also ordinary brushes for many exquisite preparation of Chalk fossils, and he does not accomplish the work by hand but by the ingenious apparatus known to dentists as the denta engine.[*] Finally, the American Museum of Natural Histor has applied this engine to many uses in the Palæontologica workshops, driving it by an electric motor and thus enabling th operator to devote his undivided attention to the fossil whic happens to be under treatment.

Many remarkable preparations of fossils contained i calcareous rocks are also being made by the careful use of solven acids. This process seems to have been first systematicall employed about thirty years ago, when the Rev. Norman Glass improving on the earlier efforts of Prof. R. P. Whitfield an Mr. J. Neilson, applied it to the preparation of the loop and spirals in brachiopod shells.[†] After some preliminar experiments he selected specimens in a state of preservatio specially amenable to treatment, and the finest examples of hi work may now be seen in the Davidson Collection of Brachiopod in the British Museum. The fossils being wholly calcareous, Mr Glass had to prevent corrosion by enveloping the parts in wax a soon as they were bared of matrix. More recently Mr. Walte F. Reid has found that the same object can be more convenientl attained by using weak acid and a protective film of collodion When the substance of the fossil itself is not calcareous bu insoluble in acid, the method of solution is still simpler, and onl needs special skill to avoid breaking the delicate residue. Thu Dr. Gerhard Holm has succeeded in removing from the Uppe Silurian limestone of Oesel skeletons of Eurypterids which loo as if they had been made from a living animal; while both he an Dr. Carl Wiman[‡] have dissolved out uncrushed Graptolites fro the Wenlock Limestone of Gothland, so that they can be studie in every detail and even embedded in paraffin to be cut int sections by the microtome. Siliceous sponges from the Chalk o Hanover have also been similarly treated by Dr. A. Schrammen and some of his remarkable preparations now exhibited in th British Museum have precisely the aspect of recent skeletons.

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[*] A. W. Rowe, "The Preparation and Mounting of Chalk Fossils," *Nat. Scienc* vol. ix (1896), pp. 303-311.

[†] T. Davidson, "Monogr. Brit. Foss. Brachiopoda," vol. iv, pp. 270-272 (Palæon Soc., 1880).

[‡] C. Wiman, "The Structure of Graptolites," *Nat. Science*, vol. ix (1896), pp. 186, 187.

Sections and dissections have always helped materially in the study of fossils; and it was the making of thin sections of fossil wood by William Nicol (of Nicol prism fame), early in the last century, that led to the preparation of transparent rock-sections and the foundation of Petrology as now understood. Laborious dissection has proved very useful in studying the structure of the chambered shells of Cephalopoda, especially of their initial chambers or protoconchs;[*] and much still remains to be done in this research by those who have the leisure and patience to make careful preparations. The latest and most ingenious application of this method, however, due to Prof. Sollas,[†] involves too great an expenditure of time and means for the ordinary amateur. The Oxford Professor has constructed a machine by which a layer of measured thickness can be ground off a fossil. He can thus examine a series of sections taken at regular and definite intervals. Each section is photographed on an enlarged scale, and when the whole fossil has been destroyed by grinding, it is represented by a series of photographs. Plates of wax, of a thickness which can be easily calculated, are then cut into the shape of the several sections recorded by the photographs. These plates are finally superposed one upon another in the exact order of the successive layers they represent, and thus they reproduce on an enlarged scale all the features of the original fossil which are visible in the rock. By this method Prof. Sollas has made a most fundamental contribution to our knowledge of the problematical Devonian fish-like organism, *Palæospondylus*; while he is now extending his work to the mouth-parts of star-fishes and other structures which are difficult to observe in fossils as ordinarily investigated.

In short, in the preparation of fossils for study there is scope for ingenuity to meet each different case; and I will only allude in conclusion to some remarkable examples of Carboniferous Polyzoa shown to me several years ago by one of the keenest Palæontologists of the last generation, the late Dr. John Young, of the Hunterian Museum, Glasgow. Dr. Young discovered that the Polyzoa in question were spinose and thus always adhered to the shaly matrix by their outer face. His method of separating them intact from the rock was to cover their fractured face with a layer of pitch, and then, as soon as it had hardened, to tear this layer off the shale. The pitch pulled the Polyzoa out of the matrix and exposed them perfectly for examination.

Most of those who have prepared fossils with the greatest success have also made their own collections. Indeed, it is essential for more exactitude in the study of Palæontology that

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[*] W. Branco, "Beiträge zur Entwickelungsgeschichte der fossilen Cephalopoden," *Palæontographica*, vol. xxxi (1879), p. 22.

[†] W. J. Sollas, "A Method for the Investigation of Fossils by Serial Sections," *Phil. Trans.*, 1903 (No. B.221).

the collecting should be done, or at least closely supervised, by those who are actually engaged in research. So many of the problems of life can only be solved when the precise geological age and circumstances of discovery of all the fossils concerned are known, that it is no longer enough to have specimens labelled with the name of a place or a district. Nor is it enough to collect a few choice examples and destroy all the imperfect or abnormal material. I do not agree with those who would enlarge our Museums to preserve the thousands of examples of a species or genus of fossils which happen to have been used for making a generalisation—I think it suffices to keep a small selection; but I am convinced that future progress depends on such exhaustive collecting as that now being done, for example, by Dr. Arthur W. Rowe in his study of the fossils of the English Chalk. Nothing should be destroyed until the research on which it has a bearing has been completed, and then a choice can naturally be made with judgment.

When adequate collections have been formed and studied in the manner just mentioned, we shall be able to distinguish between the changes which organisms have undergone merely by lapse of time, and those which seem to have depended on changes in sediment or depth of water or other conditions. We shall also discover the successive migrations and re-distributions of faunas and floras in accordance with the long series of changes in geograpical features revealed by Geology. This consummation, however, is still far distant, and there is ample scope almost everywhere for members of the Geologists' Association to become pioneers in the requisite research.

So far as the higher vertebrates are concerned, really systematic exploration has already begun to yield astonishing results. It is only necessary to compare Mr. Alfred N. Leeds's collection of Oxfordian reptiles, now in the British Museum, with earlier collections of the same kind, to realise how great is modern progress: and this does not depend so much on better opportunities as on more exact and exhaustive methods in cleaning the bones and observing their natural association in the rock. Even the most fragile specimens can now be extracted by judicious hardening with gelatine and by careful envelopment with plaster or linen bandages—a process which Mr. William Davies was one of the earliest to employ,* and which American collectors have subsequently improved to perfection. Moreover, the exact localities of discoveries even in wild countries are now so carefully noted, that old trails can be resumed without difficulty; and I know no more striking illustration of this exactitude than that which enabled Mr. Santiago Roth, of the La Plata Museum, to return to a spot in Neuquen, Argentina, and recover the skull

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* W. Davies, "On the Preservation of Fossil Mammalian Remains found in Tertiary Deposits," *Geol. Mag.*, vol. ii (1865), pp. 239, 240; also *ibid*, p. 93.

with a large part of the skeleton of the horned tortoise, *Miolania*, where he had previously found only a doubtful fragment of the animal.*

The collecting of vertebrate fossils, however, on a large scale, involves so much expenditure that it can rarely be undertaken by a single individual. It is generally done under the auspices of public institutions, which are not only able to obtain funds and the services of experts, but can also overcome difficulties when the rights of landowners have to be considered. The Universities and Museums of North America, especially, have devoted attention to such researches for many years, and made so many remarkable contributions to Palæontology that we are liable to overlook the possibilities and results of similar work elsewhere. The discoveries of Moreno, Ameghino, Roth, Hatcher, E. Nordenskjöld, and others in South America during recent years have been almost equally remarkable. The explorations of Mr. Beadnell, of the Egyptian Geological Survey, and Dr. Andrews, of the British Museum, in the Egyptian desert, have revealed the ancestry of the elephants and added immensely to our knowledge of other mammals of which scarcely any extinct representatives were previously known. The diggings of Grandidier, Forsyth Major, and the missionaries in the swamps and caverns of Madagascar, have yielded unexpected evidence of strange gigantic lemurs and other animals in that country. The expeditions of Prof. E. C. Stirling and Prof. J. W. Gregory have shown how much success awaits systematic bone-digging in Central Australia. Finally, Prof. W. Amalitzky, of the University of Warsaw, has for some years been excavating apparently inexhaustible deposits of reptile-skeletons in the Upper Permian rocks of Northern Russia. Palæontology as now studied, indeed, is no longer dependent on casual quarrying or chance excavating for its best and most satisfactory materials. Collecting is done systematically to solve certain definite problems which are formulated before the work is begun; and amateurs, who are unable to give personal service but happen to be possessed of the financial means, cannot promote Natural Science better than by entrusting funds to some of the public bodies who are actually at work and only need resources to extend their operations.

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* F. P. Moreno, "Note on the Discovery of *Miolania* in Patagonia," *Geol. Mag.* [4], vol. vi (1899), pp. 385-388.

THE RELATIVE AGES OF THE STON IMPLEMENTS OF THE LOWER THAME VALLEY.

By M. A. C. HINTON and A. S. KENNARD.

[*Read April 7th, 1905.*]

INTRODUCTION.

THERE are few questions in geology which have receive more attention in recent years than the antiquity of man and yet a careful survey of the subject must convince one that, i this country at any rate, our knowledge is still very far from satisfactory state. Perhaps the principal cause of this conditio of things arises from the fact that flint implements have bee exploited so largely by the mere collector. Too often the heigh of the deposit in which the implements occur, the nature of th beds, and the associated fauna are quite neglected. All that i desired is a collection of implements, and not a collection of facts Another source of confusion arises from a lack of accuracy in th use of such terms as Palæolithic, Acheuléen, Chelléen, etc. A an early stage of the question Lord Avebury divided stone implements into the two well-known groups, Palæolithic an Neolithic, and this primitive classification, with the addition o the much debated "Eoliths," is the one usually adopted in thi country. On the Continent, however, far more elaborate system are in vogue. Thus Monsieur A. Rutot has divided the pre Neolithic into ten groups, the Eoliths comprising four, the olde Palæoliths four, and the newer Palæoliths two.* The classification which was satisfactory in the infancy of our science i obsolete to-day. The old Linnean genera have been divided and subdivided out of recognition, no system is final, and with the growth of our knowledge new classifications are bound to be made.

Though, as already noted, the early system is the one generally used in this country, yet it must be remembered that successful attempts have been made in dividing the Palæoliths. Of these, we would notice two, the first by the late Sir Joseph Prestwich, and the second by Mr. S. Hazzledine Warren. The first-named, in his two papers on the flint implements from the neighbourhood of Ightham,† has practically marked out the lines on which future research should be made. Applying strati-

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* 1904. A. Rutot, *Mem. Soc. d'Anthrop. de Bruxelles*, tome xxiii.

† 1889. J. Prestwich, "On the occurrence of Palæolithic Flint Implements in the Neighbourhood of Ightham," *Quart. Journ. Geol. Soc.*, vol. xlv, p. 270; 1891. "On the Age, Formation, and Successive Drift Stages of the Valley of the Darenth," *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 126.

graphical evidence to the problem, he conclusively proved that there was a distinct succession in the flint implements from North Kent. He pointed out that vast changes had taken place in that area since some of these implements had been fashioned, whilst we are indebted to him for first distinguishing the earliest handiwork of man in these islands in the rudely chipped flints found in the Plateau Gravels, and for separating the older Palæoliths, which he termed the "hill group," from those found in the terraces of the present river systems. Mr. S. Hazzledine Warren's paper is of the utmost importance to all students.* It is impossible here to give a *resumé* of his views, but he points out that many important conclusions can be drawn from the condition of the flint implements, which though occurring in one deposit are of various ages. A classification with sequence dates is given, being a modification of the one proposed by M. de Mortillet, and though we find ourselves forced to disagree with the details, yet there can be no doubt that it is a great advance on any previous work in this country.

It has always appeared to us, however, that if any advance is to be made it must be on stratigraphical lines. The definite succession from this standpoint once being settled, and definite datum-lines laid down, the question of the successive stages in the evolution of flint implements will then be easier to solve. For some years past we have been studying the Pleistocene succession in the Lower Thames Valley, during which many temporary and permanent sections have been examined, and nearly all the large collections have been inspected. It is indeed fortunate that the immediate neighbourhood of London should yield so much important evidence relating to the antiquity of man. It is to be doubted if any locality has yielded so many implements as the neighbourhood of Swanscombe. Sections in the Pleistocene beds abound on every hand, and the great difficulty has been to visit them all. Besides the collectors, who are, alas ! too common, there are many diligent students, and to these we would tender our thanks for the many kindnesses we have received at their hands. We would particularly mention Dr. Frank Corner, Benjamin Harrison, Robert Elliott, S. Hazzledine Warren, W. J. Lewis Abbott, M. C. Heys, W. M. Newton, Percy Martin, F. J. Bennett, J. P. Johnson, Gilbert White, and the late H. Stopes.

We would also place on record our indebtedness to many of the labourers with whom we have been brought in contact, from whom we have received many kindnesses, and from whom we have gleaned much information.

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* 1902. S. Hazzledine Warren, "The Value of Mineral Conditions in determining the Relative Age of Stone Implements," *Geol. Mag.*, N.S., Dec. iv, vol. ix, p. 97.

GEOLOGICAL HISTORY OF THE LOWER THAMES VALLEY.

Exigencies of space prevent us entering minutely into all the details of the geological history of the Lower Thames Valley, but it will be necessary to give the broad outlines. There is no need to enter into the theory of river action, or the origin of gravel spreads or terraces. They are now well known to all geologists, and such terms as base-level, graded, etc., are now in common use. It is indeed fortunate that we have in our area a datum-line prior to the establishment of which the Lower Thames Valley could not have existed. As was pointed out years ago by the late Sir Joseph Prestwich this datum-line is furnished by the Lenham Beds, which occur in fragmentary patches on the North Downs, and are the most recent remains of the extension of marine conditions over the area.

Though a satisfactory examination of the fauna of these beds has still to be made, yet there can be no doubt that they are rightly placed in the Lower Pliocene, and probably much older than the Coralline Crag of Suffolk. From the time when this old Pliocene sea retreated from our area until quite modern times when the Lower Thames became tidal, there is no evidence of the presence of the sea. There is evidence that at times it was close to our district, whilst at others it was far distant, but of its actual presence there is absolutely no evidence. We are dealing with an area which has been sculptured into its present shape by the action of rain and rivers. It is a long and varied history of elevation and consequent erosion until the streams had reached their base level, and deposition ensued, to be followed by a further elevation, erosion and deposition. Apparently at one stage there was a period of depression, or if not an actual depression of the land a ponding back of the waters, whilst its latest phase is one of interrupted subsidence.

Much of its early history is very obscure, and would need many years of patient work and investigation to thoroughly elucidate, but the later stages are well marked and by no means difficult to decipher.

Starting from the first datum-line, the Lenham Beds, we have marine conditions existing over the area. It is therefore clear that the commencement of the Lower Thames Valley must be much later. The next oldest deposits we have are a fragmentary series of fluviatile gravels capping the highest portions of the North Downs, and known as the Plateau Gravels. It is from these gravels that the chipped flints have been obtained which are claimed to be the earliest relics of man in these islands. The questions as to the origin and the relative age of these gravels have been so conclusively dealt with by the late Sir Joseph Prestwich[*] and

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[*] 1891. J. Prestwich, "On the Age Formation and Successive Drift Stages of the Valley of the Darenth," *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 126.

Professor T. Rupert Jones,* that there is no need to discuss them here. Whatever opinion there may be with regard to the chippings on these flints, there is no doubt as to the relative age and method of deposition. No geologist doubts the conclusion that these gravels have been deposited by streams flowing north from the now destroyed dome of the Weald. If one stands on the crest of the chalk escarpment at Wrotham Hill with the broad valley of Holmsdale in front, and the still broader and deeper Medway valley seen through the Shode gap, the enormous amount of time which has elapsed since these gravels were deposited is forcibly impressed on one's mind. Where was a high range of hills is now a peaceful valley, the old rivers have disappeared, their degenerate descendants have ceased long ago to erode their beds, and all these changes have occurred since man first lived in Kent.

Amongst other places where this gravel occurs may be noted Terry's Lodge, 770 ft. O.D., Wrotham Hill, 760 ft. O.D., Plaxdale Green, 637 ft. O.D., Fairseat, 690 ft. O.D., Ash, 490 ft. O.D., Cotman's Ash, 665 ft. O.D., Wick Farm, 697 ft. O.D., North Ash, 460 ft. O.D., West Yoke, 460 ft. O.D., Morant's Court Hill, 700 ft. O.D., Tatsfield, 780 ft. O.D., and Titsey Hill, 864 ft. O.D. The great differences in level of these patches clearly show that they cannot all be of the same age, and that several base-levels are represented, conclusions which are supported by an examination of the implements, the lower levels yielding more advanced types than the higher.

The elevation of the Weald without doubt was brought about by a series of intermittent elevatory movements, each movement producing a fresh base-level for the streams. But though much of the evidence has been destroyed, it is possible that a careful survey will yet enable us to elucidate much of the past history, and to work out minutely the true succession of these gravels. As to the age of these beds they must be later than the Early Pliocene. Monsieur A. Rutot is of opinion that they should be assigned to the Middle Pliocene, an opinion which has received much support amongst English geologists.†

Is it too much to hope that there may still be left some fossiliferous portion which will settle conclusively this question? One thing, however, is certain. The deposition of this group of gravels must have extended over a considerable period of time. At present we have no means of ascertaining the duration of the period from the deposition of the Lenham Beds to the earliest Plateau Gravel, or of the time during which these latter beds were deposited.

The importance of the next group of gravels was first pointed

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* 1894. T. Rupert Jones, "On the Geology of the Plateau Implements of Kent," *Natural Science*, vol v, p. 269.

† 1903. A. Rutot, "Esquisse d'un comparaison des Couches Pliocènes et Quaternaires de la Belgique avec celles du sud-est de l'Angleterre," *Bull. Soc. Belge de Géologie*, tome xvii, pp. 57-100.

out by the late Sir Joseph Prestwich. They are not all c same age, and represent, in all probability, several base-l From their stratigraphical position they must be newer tha Plateau Gravels, and older than any terrace gravels in the valley, and this conclusion is amply confirmed by an examir of the implements. These gravels are the only evidence o changes in the physiography of our area. The Darentl captured many of the small streams flowing from the Wealc Holmsdale had been partly excavated. For our knowlec these deposits we are almost entirely indebted to Mr. Ben Harrison, whose researches are so well known. This grou which Sir Joseph Prestwich applied the term High Le Limpsfield Stage, includes the gravels at Limpsfield, 520 ft. (Farley Hill, two miles east of Limpsfield, 450 ft. O.D.; Bou Hill, near Dunton Green, 357 ft. O.D.; Snag Farm, near borough, 340 ft. O.D.; Broomsleigh, Ightham, 460 ft. (Bewley, Ightham, 435 ft. O.D.; Cop Hall, Ightham, 410 ft. (and a series at West Wickham, ranging from 350 ft. to 400 ft. All these are gravels of the tributaries of the Thames; but is one patch which, in all probability, belongs to the main s —Swanscombe Hill, 320 ft. O.D. This, in our opinion, be to this stage, though it is considered by Sir Joseph Prestwicl Dr. A. E. Salter to belong to the Plateau group.* No or remains have as yet been found in these gravels. Hither have been dealing almost solely with the gravels of the trib streams, but from the High Level stage the evidence is pract confined to the main valley, where the sequence of events i shown.

At a much lower elevation than these High Level gravels o the highest terrace of the Thames. This is well seen at Da Heath, 136 ft. O.D., and Dartford Brent, 131 ft. O.D. I opinion these gravels should be grouped with the Wimbl Common gravel, 180 ft. O.D., and Kingston Hill, 17 O.D. The well-known terrace at Greenhithe and North 100 ft. O.D., must be considered as belonging to a stage. This Dartford gravel is of the greatest importance, it is from these beds that the first traces of a contemporary have been obtained: Mr. F. C. J. Spurrell having found *El primigenius*, *Rhinoceros* sp., *Bos*, *Equus*, *Cervus*, and four sp of mollusca, including *Corbicula fluminalis* at Dartford B After the deposition of the Dartford gravel an elevation o land occurred, probably to a height of about 30 ft., and o Thames eroding its bed to base-level, the deposition of an sheet of gravel ensued. This is the wide-spread sheet comn known as the High Terrace. It is well developed in the

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* A. E. Salter, "Pebbly and other Gravels in Southern England," *Proc. Geol.* vol. xv, 1898, p. 266.

† E. T. Newton, "On a Human Skull and Limb Bones found in the Palæolithic Gravel at Galley Hill, Kent," *Quart. Journ. Geol. Soc.*, 1895, vol. li, pp. 521 and 522.

district, at Grays, Swanscombe, Greenhithe, and Northfleet. This second terrace of the Thames had until lately yielded but few organic remains, *e.g.*, the well-known human skeleton from Galley Hill, *Elephas* and *Leo* from a brickearth of this age at Swanscombe, and *Elephas* and *Hippopotamus* from Milton Street. A small excavation made during the last few years at Swanscombe has, however, yielded a large and varied fauna. This section was visited by the Association in 1901.* Amongst the more remarkable forms occurring may be noted *Microtus intermedius* and *Trogontherium*, both hitherto unknown in this country later than the Forest Bed, Reindeer (*Rangifer tarandus*), *Elephas antiquus*, and Pig (*Sus scrofa*), whilst the following extinct species of mollusca were obtained: *Pyramidula ruderata*, *Vivipara diluviana*, *Planorbis vorticulus*, *Paludestrina marginata*, *Unio littoralis*, *Pisidium astartoides*, *Corbicula fluminalis*, and *Neritina grateloupiana*.

This last form, which was identified by Dr. O. Boettger, is indeed noteworthy since hitherto it was unknown in any deposit more recent than the newer Miocene of Germany, though a near ally, *N. danubialis*, still lives in the south-east of Europe. We hope to give at a future date an extended notice of this interesting fauna.

At the close of this stage an elevation of the land occurred to the extent of about 90 ft. The Thames and its tributaries at once commenced to erode their beds and this vertical erosion continued until base-level was again reached. Measured by erosion the time that elapsed between the deposition of the Swanscombe gravel and that of the Crayford brickearths is very much greater than between the latter and the present time, for the lateral erosion was enormous. Practically the Lower Thames Valley as we see it to-day was excavated during that period, and a similar erosion also occurred in the tributary valleys. In fact, at the close of this stage the land had practically assumed its present appearance. When the Thames had eroded its bed to base-level, deposition ensued, and an enormous amount of detritus was accumulated. This is the wide spread often spoken of as the Middle Terrace. On the north side of the Thames in the vicinity of London it is a vast terrace of gravel, whilst further east we meet with the brickearths of Ilford and Grays.

On the south, near London, we have another gravel spread and the relatively similar brickearths at East Wickham, Crayford, and Northfleet. These brickearths are of great interest. They attain a thickness of at least 30 ft., and at Grays and Crayford they are banked against an old buried cliff, and in both cases an old land surface is covered by them. It will at once be seen that these brickearths represent an abnormal condition of the

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* *Proc. Geol. Assoc.*, vol. xvii, 1901, pp. 138 9.

Thames. It has been suggested that the river was ponded bacl by glaciers filling the bed of the North Sea, a theory which wa first propounded by the late Mr. A. Belt. On the Continent thi theory has received far more support than in this country, thoug it must be remembered that a late post-Glacial submergence wa advocated by the late Sir Joseph Prestwich.* It is indeed not worthy how the Palæolithic floors which in this country are nearl all of this age, and which are true land surfaces, are covered by deposit obviously laid down either by still or slowly-movin water. This is true of Crayford, Grays, and Northfleet, all of th same age, judged by stratigraphical evidence, and all presentin exactly the same conditions. At Caddington, Mr. Worthingto G. Smith found the Palæolithic floor covered in the same manne and this at an elevation of 560 ft., whilst at Stoke Newington h noted a similar condition of things at 90 ft. O.D. He says "It is clear that the first change which took place on t Palæolithic floor was the mere covering of it by fine river san often full of the shells of land and freshwater mollusca. T the present day these shells are as a rule unbroken, eve the large fragile shells of *Helix nemoralis*, Linn., are foun perfectly intact. There is no indication of any violent movemen of the gravel and sand. It will be remembered that precisely th same conditions hold good respecting the covering of th Palæolithic floor on the hill top at Caddington." It is therefor necessary to account for this widespread phenomenon. I Germany and especially in Belgium the view that there was one stage of the late Pleistocene period a vast flood whic covered all the low-lying ground, and even many of the hills, generally accepted. If the Belgian and German geologists a correct in their conclusions, a similar state of things must ha occurred in the Thames Valley. But even if the North Sea we blocked by glaciers there would still be an outlet for the wate through the Straits of Dover, unless at this period the chalk w still continuous from Dover to Calais.

We know that some of the rivers of Northern France an Southern England must at an early stage have formed part of t Thames-Rhine system, and in all probability their combine streams flowed through land where now exist the Straits of Dove We also know that in late Pleistocene times some of the streams had been betrunked by the inroads of the sea, so that is just possible that the chalk was continuous from Dover Calais with a gap where the old river went, and that the pent-u waters, unable to escape northward, burst the southern barri through the gap, greatly enlarged and deepened it, and the Strai of Dover were in their initial stage.

There is however, no need to pursue this question further,

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* 1892. J. Prestwich, "The Raised Beaches, etc., of the South of England," *Qua Journ. Geol. Soc.*, vol. xlviii, pp. 263-343.

† Worthington G. Smith, "Man, the Primeval Savage," 1894, p. 237.

that is necessary for our purpose is to point out that the Thames lower brickearths represent a definite stage. The contemporary fauna is well known, abundant animal remains occurring at Grays, Ilford, Crayford, and elsewhere, and a few plant remains are also known. The most noteworthy mammalia are *Elephas primigenius*, *Elephas antiquus*, *Rhinoceros megarhinus*, *R. leptorhinus*, *R. antiquitatis*, *Ovibos moschatus*, and *Spermophilus erythrogenoides*.

After the deposition of the brickearths an elevatory movement ensued, and when it ceased the land was about 20 ft. higher. It probably did not necessitate any great length of time to enable the Thames to grade its bed, and another terrace of gravel was then deposited. This is the fourth terrace that can be recognised, although it is often spoken of as the third terrace. In our area it has yielded few organic remains, but in all probability the mammoth remains mentioned by Mr. F. C. J. Spurrell as having been dredged from the Thames were obtained from it.* At Westminster, however, it yielded to Mr. W. J. Lewis Abbott an abundant fauna and a few plants†.

After the deposition of this terrace a great elevation of the land ensued. The extent of this elevation we are unable to state with accuracy, though it must at least have been 90 ft. The Thames and its tributaries at once commenced to deepen their channels, and this they did to a degree varying with their distance from the sea. This channel was a deep ravine whose existence is only known by chance borings. Thus the old bed of the Lea has recently been shown to be 57 ft. below the present surface at Walthamstow.‡ At Tilbury the old bed of the Thames was found at 76 ft. from the surface, whilst the following figures of the thickness of the alluvial deposits prove conclusively the existence of this buried channel: South Shoebury, 54 ft.; Canvey Island, 70 ft.; Rochester, 46 ft.; Greenhithe, 50 ft.; Hoo Fort, 56 ft.; Isle of Grain, 61 ft.; Battersea, 31 ft.; Lambeth, 33 ft.; Southwark, 34 ft.; Thames Haven, 78 ft.; Tilbury Fort, 67 ft.; Tilbury Dock, 68 ft.; Northfleet, 72½ ft.; Shorne Mead, 77½ ft.; Cliff Fort, 76 ft.; Crossness, 71½ ft.; Belvedere, 50 ft.; Aveley Marsh, 70 ft.; Limehouse, 49 ft.; and Sheerness, 75 ft.

We do not know the full extent of this last elevation, since there is no evidence that the Thames had reached base-level, and, moreover, the deepest part of the buried channel may not yet have been touched. At this period and for long afterwards what is now the North Sea must have been dry land.

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* F. C. J. Spurrell, 1889, "On the Estuary of the Thames and its Alluvium," *Proc. Geol. Assoc.*, vol. xi, p. 227.

† W. J. Lewis Abbott, 1892, "The Section Exposed in the Foundations of the New Admiralty Offices," *Proc. Geol. Assoc.*, vol. xii, pp. 346-356.

‡ T. V. Holmes, 1903, "Additional Notes on the Section Shown in the New Reservoirs in the Valley of the Lea, near Walthamstow," *Essex Nat.*, vol. xii, pp. 224-231.

Following this elevation an intermittent reverse moveme ensued, the land gradually sank, with consequent depositi of detritus, until at length the Lower Thames became tid and it assumed its present appearance of a sunken land. to the former extent of the Thames we would quote t words of Mr. Whitaker: "We must then infer that at t time when this, the broadest tract of alluvium in our district, w formed the valley of our chief river must have reached ma miles eastward of Foulness, and of the neighbouring marsh and that fairly high land must have extended north-eastwa from Sheppey far out into what is now sea, so that the Crou was then only a tributary of the Thames. It would follo therefore, that since this late geologic period, or in Neolitl and later times, very many miles have been lost from our s board in Eastern Essex, and in Northern Kent; to such an exte indeed as to destroy the whole of the right side of the bro valley of the Thames, and to leave only the alluvium of the l side of the valley bottom as a sign of the former course of t river. Perhaps the deep channels that now occur north-eastwa from the Nore are the direct descendants of the former extensi of the estuary of the modern Thames."*

We have spoken of the intermittent nature of this subsiden and this is fully borne out by the character of the Holoce deposits. These were seen at Crossness to consist of two d tinct layers of peat with a dividing bed of tidal clay, and underlying bed of sand. From archæological evidence we a able to fix the age of the upper peat as of Bronze Age, and was certainly dry land in Roman times since Roman buri occur in it.†

We have thus in the Lower Thames Valley a series of ba levels, each base-level representing a pause in the elevation the Weald, and these may be grouped into eight stages:

1. The Plateau Gravels.
2. The Hill Gravels.
3. 1st Terrace, or Dartford Heath Gravel.
4. 2nd Terrace, or Swanscombe Gravel.
5. 3rd Terrace, or Crayford Brickearths.
6. 4th Terrace.
7. The Buried Channel.
8. Holocene Alluvium.

These are the eight stages into which we would divide tl history of the Lower Thames. The first two stages will n doubt be sub-divided in the future, but our information is n definite enough at present to enable us to do this. They cov an enormous amount of time, and judged by the standard erosion far more than all the remainder together.

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* W. Whitaker, 1889, "The Geology of London," *Mem. Geol. Survey*, p. 476.

† F. C. J. Spurrell, "The Estuary of the Thames and Its Alluvium," *Proc. Geol. Asso* 1889, vol. xi, pp. 210-230.

Since this paper was written, Mr. H. W. Monckton, F.G.S., has given us a history of part of the Upper Thames in recent geological times,* and, since his conclusions are largely derived from a different area, it is interesting to compare his views with ours. Though we both recognise eight stages, yet there are differences between our views.

Mr. Monckton's first stage, "The Sarsen stones, probably the relics of the first land surface after the marine lower Barton," is unrepresented in our area.

His second stage, "Completion of the elevation of the Weald in Pliocene times, and deposition of the river gravel with large flints at Upper Hale and Cæsar's Camp, Aldershot, and on the North Downs at Newlands Corner," etc., is the same as our first stage, the Plateau Gravels.

The third stage recognised by Mr. Monckton, "Gravel of Goring Heath, Cane End," etc., is probably our second stage, the Hill Gravels.

The Chalky Boulder Clay, which is Mr. Monckton's fourth stage, is not represented south of the Thames, but in all probability it comes between the Hill Gravels and our third stage, the Dartford Heath Terrace. This latter terrace Mr. Monckton has omitted, probably classing it with his fifth and our fourth stage, the 100 ft. terrace.

His sixth stage, "The gravel of the plain between Brentwood and the River Colne, about and a little over 50 ft. O.D.," is the equivalent of beds in our area which we have considered as belonging to our fifth stage, the Brickearths of Crayford, which Mr. Monckton considers the seventh stage.

Our next two stages, the Fourth Terrace and the Buried Channel, are not recognised by Mr. Monckton. Whilst we both agree in considering the alluvium as the last stage. It may be noted however that the buried channel does occur in the upper part of the Thames, for Mr. H. J. Osborne White, F.G.S., notes the alluvium at Hurley as being 38 ft. in thickness.†

The following table is an epitome of our views:

H. W. Monckton.		M. A. C. Hinton & A. S. Kennard.	
1st stage.	Old land surface	Not recognised.	
2nd „	Upper Hale Gravel	1st stage.	Plateau Gravel.
3rd „	Goring Heath	2nd „	Hill Gravel.
4th „	Chalky Boulder Clay	Unrepresented in Kent.	
5th „	100 ft. Terrace	3rd stage.	Dartford Gravel.
		4th „	100 ft. Terrace.
6th „	Gravel of the Plain	5th „	Crayford Brickearths.
7th „	Crayford Brickearths		
	Not recognised	6th „	Fourth Terrace.
	Not recognised	7th „	Buried Channel.
8th „	Modern Alluvium	8th „	Modern Alluvium.

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* "Excursion to the Farnham Gravel Pits," etc., *Proc. Geol. Assoc.*, 1904, vol. xviii, pp. 410-414.

† H. J. Osborne White, F.G.S., "Excursion to Henley-on-Thames," *Proc. Geol. Assoc.*, vol. xviii, 1904, p. 414.

THE STONE IMPLEMENTS OF THE LOWER THAMES VALLEY.

We have already shown on stratigraphical evidence that eight distinct stages may be recognised. An examination of the implements has convinced us that several of these are characterised by different groups of implements, and that when this is not so it arises from the fact that we have no implements from that horizon.

There are two axioms to be always borne in mind when considering the implements from any given deposit. First that a bed of gravel may yield, and as a rule does yield, not only the implements that were in use at the time of the deposition of the bed, but also older implements which have been derived from earlier deposits. This is well seen in the gravel which is at the present time dredged from the bed of the Thames at Erith and elsewhere. This contains much rolled implements, evidently belonging to the second terrace, with less rolled flakes and tools obviously derived from a deposit of the same age as the Crayford brickearths, and accompanied by Neolithic flakes and implements, bronze tools, Roman pottery and tobacco pipes.

The second axiom to be remembered is that, since many of these gravels have been dry land soon after their deposition, implements of various ages have been dropped on their surfaces. This is not often the cause of confusion, since, as a rule, these later implements differ in colour from those belonging to the deposit. But it must be pointed out that through ignoring this axiom the statement has been repeatedly made that Palæoliths and Eoliths occur in the same gravel, whereas, as a matter of fact, the former have been dropped at a later period on the surface of the Plateau Gravel.

Perhaps another word of caution may be added with regard to the question of colour conditions. True inferences can only be drawn from these after a careful study of the implements from a gravel. Thus at Milton Street one can obtain practically all stages of patination and colour, and all undoubtedly contemporary implements, the differences arising from varying positions in the bed, the white or bluish-white examples always coming from the upper part. A final word of caution may be given with regard to implements obtained from the workmen. There is no need to mention forgeries; these are now too well known, though they are often very skilfully made and difficult to detect. But workmen are apt to carry implements from one pit to another for sale. Thus until lately the new Hythe pit at Aylesford had the reputation of yielding no implements, and consequently collectors never visited it. Hence all the implements found were passed on to the foreman of Wagon's pit to be disposed of. Since these two pits are at the same level, it is no great importance, but the possibilities of this system must be apparent to all. It is, therefore, much more satisfactory to work in such a neighbourhood as Grays, where the workmen have no knowledge of flint implements, than the vicinity of Swanscombe, where even school children and women are well acquainted with them.

IMPLEMENTS OF THE PLATEAU GRAVELS.

Few questions have been more keenly debated than the origin of the chippings of these so-called Eoliths. Considered by a large number of authorities to be of human origin, yet there are still many who can only see in them the result of natural agencies. More recently the view has been advanced that though human yet they are only of Palæolithic age. It is greatly to be regretted that needless acrimony has been introduced into the subject, since it has tended to obscure the points at issue. It must be obvious to all that the Palæoliths from the 100 ft. terrace cannot represent the infancy of the stone culture, and this also applies to the still older Palæoliths from the Hill gravels, which, though rude, are not the work of prentice hands. It must have taken a very long period for man to have advanced to that stage. We are, therefore, justified in searching the still older fluviatile deposits for traces of man, and it is in the Plateau Gravels that these rudely chipped flints are found. Their geological position therefore yields strong presumptive evidence of their human origin. It is only reasonable to suppose that man's earliest implements were of an extremely primitive character: natural stones chosen for their suitability, used, and then thrown away. How difficult it would be to discriminate between such a tool and a flint which has been subjected to battering in a torrent. No one would for a moment accept the Tasmanian tools as implements, yet we know they were made and used. These facts are sufficient to show that there is no inherent improbability in the Eoliths.

In the first place it must be conceded that there is a tendency to accept too much. When one carefully considers the results of stream action it must be admitted that natural agencies can chip and abrade flints. A careful examination of river gravels will produce many such. We have seen a large number of flints which have been considered to be Eoliths which in our opinion are either doubtful or else natural; yet, when these are eliminated, there still remains a large number which we consider to show the handiwork of man.

There are three causes suggested by the opponents of Eoliths to account for the chippings.

1. Beach action.
2. River action.
3. Glacial action.

Since these gravels are fluviatile, the first cannot be considered a satisfactory solution. Of course it is possible and even probable that some of the materials of the Plateau Gravels may have been derived from old Pliocene beaches, but the flints taken as a whole are totally unlike any beach material with which we are acquainted. But the great objection to beach action is that it bruises and abrades the whole of a flint, especially the weakest part, the edge. Eoliths, on the other hand, are usually worked on a portion of the edge only. Many exhibit delicate points which beach action would destroy at once.

There can be no doubt that there are two different operations represented in many Eoliths: 1. Chipping; 2. Battering. Specimen will be noticed with flakings which have been partially effaced by subsequent rolling or battering, whilst some are only flaked and not bruised or battered. We have carefully examined many beach flints, and though it must be admitted that there are points of resemblance, yet the differences are such as to prove conclusively that the causes are different. All the beach pebbles we have seen are bruised, whilst many Eoliths are not bruised And this objection to beach action also applies to river action Of course it is possible that in the early stages of the denudation of the Weald the streams were torrential in their character What the effects of a torrent on the flints in its bed would be we cannot say definitely, since such a condition of things does not exist to-day; but in all probability its effect would be similar to beach action, if not identical. If Eoliths are the result of river action then they ought to occur in the terrace gravels, but when they occur there they are obviously derivatives, the colour and chippings still there, but differing so much from the other flints tha their origin can at once be settled. Characteristic Eolithic working does occur on some Palæolithic flakes, but then that i confirmation as to their human origin. Lastly, we have glacia action. This is always the last explanation, but to invoke glacia conditions to account for a few chippings and scratches on a few flints is a vast return of theory for a small investment of fact.

An important confirmation of the Eoliths has lately been made in the Transvaal by our friend Mr. J. P. Johnson. He ha found in the neighbourhood of Johannesburg an identical succession with that of the South of England, *viz.*, Eoliths, Hill grou implements, Palæoliths and Neoliths.* They are found in th same stratigraphical succession there, the only difference being, o course, in the material. Now it would appear more reasonabl to accept the Eoliths as man's handiwork than to suppose tha in these two areas some extraordinary natural conditions which cannot be paralleled at the present should have happened at the same relative time. It is obvious that this discover

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* 1903. J. P. Johnson, "On the Discovery of Implement-bearing Deposits in th Neighbourhood of Johannesburg," *Trans. Geol. Soc. South Africa*, vol. vi, pp. 60-67.

in South Africa completely rules the glacial and marine theories out of court, for up to the present no one has ventured to suggest that either marine or glacial conditions existed in the Transvaal in Tertiary times. There is only the last objection to be considered, and it is one which was first stated by Mr. Worthington G. Smith, and since his knowledge of flint implements is very great, his objection is worthy of consideration. He says,* "Some of the Ightham examples and some of the battered edges are no doubt human in origin, but the oldest can be no older (as I think) than tools of the class here illustrated (*i.e.*, older Palæoliths), and the chipping of the majority when human far less old. Tabular pieces of flint with battered edges are common in all implementiferous gravels; they occur with the better classes of tools, and as the better class of tool occurs with the Ightham tabular examples, it is obvious that the makers of the Kentish Plateau implements could do far better work than the mere battering of edges when so inclined." Briefly stated, his position is that these tools are Palæolithic. But the term Palæolithic is a misleading one, for it includes the cave implements, the implements of the 100 ft. terrace, and the still older hill group tools. It is with the last group that Mr. Smith would class them, but this conclusion is founded on an error. Palæoliths and Eoliths do not occur together, except as surface finds. When Mr. Smith wrote the above no sections had been made in the Plateau Gravel. All the implements were surface finds. But since then several pits have been specially sunk, and in all these Eoliths only occurred, except in the disturbed surface-soil, where Palæoliths were found, and we venture to think that had Mr. Smith known this he would have altered his conclusions. At Brand's Hatch or Speedgate, 490 ft. O.D., is a gravel spread to which considerable attention has been paid by us. There are no sections, unfortunately, and all the implements are surface finds. They are easily divided into four groups.

1st. Eoliths.—These are the characteristic, deeply-stained flints with chippings on their edges. The natural and the artificial surfaces are the same colour. Many of the flints retain traces of the matrix in which they were formerly embedded, an iron pan. Some are rolled and have been obviously derived from a much higher altitude, probably from the now destroyed Wealden highlands.

2nd. Transitional.—These are more plentiful than the Eoliths, and it is these implements which Mr. Worthington G. Smith has referred to as "tabular pieces of ochreous flint with lighter coloured battered edges found on the Plateau near Ightham."† In the first place it is obvious that they must be much newer

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* Worthington G. Smith, "Man, the Primeval Savage," 1894, p. 217.
† *Op. cit.*, p. 217.

than the group which we have just described. The condition of the flakings clearly shows that they were used and discarded, and they have lain on or near the surface till the present time. The first group were laid down by a stream, whilst these latter were dropped on the surface of this river-bed when it became dry land. A careful examination of these transitional forms reveals the fact that they show a decided advance on the true Eoliths. Attempts have been made to chip a flint to the required shape, and the chippings are much larger. It may be mentioned that these implements are found elsewhere on the Plateau, and they form a well-marked group.

3rd. Older Palæoliths.—These are not common, being only represented by a few flakes and implements of the characteristic light-brown colour.

4th. Neoliths.—These are by far the most abundant, and which call for no extended notice.

Thus, on this isolated patch of gravel, we have traces of, at least, four stages: one represented by the deposit, and three by successive occupations. After a careful survey of the Kentish Plateau, and an examination of all the available evidence, we venture to think that, even if we eliminate all the doubtful examples, there still remains a large number of Eoliths, which are undoubtedly the work of man. The oft-repeated challenge of Sir Joseph Prestwich to produce naturally-chipped flints identical in shape with the Eoliths has never yet been accepted. The corroborative evidence from Belgium, France, Germany, and South Africa still further strengthens our conclusion. To endeavour to explain them by natural causes is to create enormous difficulties which are to us quite insuperable. The nature and conditions of the work, and the stratigraphical position of the Eoliths, are so completely in agreement with what one would infer from a study of Palæolithic implements, that there is no resisting the inference that in these rudely-chipped flints we have the earliest evidence of the existence of man in these islands, and it is to the enthusiasm and knowledge of Mr. Benjamin Harrison and the late Sir Joseph Prestwich that their true value has been recognised.

IMPLEMENTS OF THE HILL GROUP.

It is always to be expected in arbitrary divisions, such as are bound to be made in any scheme of classification, that there are objects which will not be classified. In dealing with the handiwork of man, when one finds a progressive development, lines of separation, which are founded upon the intrinsic evidence of the objects dealt with, must always fail, hence the stratigraphical divisions have an advantage. We have already discussed the Eoliths and the group which we have called transitional. This latter group have no stratigraphical position at present. One can only say they are newer than the Eoliths, and are presumably older than the hill group implements. The hill group tools, however, possess a stratigraphical position. They occur in gravels which were laid down between the Plateau Gravel and the highest terrace of the Thames. Unfortunately all these gravels are very fragmentary, and the implements are nearly all surface finds.

Mr. Worthington G. Smith called attention to these implements, and pointed out that they must be very much older than the later Palæoliths, and Mr. Warren has noted that they must cover a long period and may be capable of sub-division. But both these observers were only acquainted with them as derivatives in newer gravels, and their conclusions were derived from their condition. The stratigraphical position of these older Palæoliths was first established by Sir Joseph Prestwich,* who clearly demonstrated that they must be much older than the contemporary implements of the highest Thames terrace.

These hill gravels are perhaps best studied in the neighbourhood of Ightham, where they are well developed, but the two most prolific localities are West Wickham and Ash. On the chalk hills they are usually stained a light brown, but they also occur of a deep ochreous here. The Ightham specimens are often white. In the newer gravels they are not uncommon, where their colour and condition at once mark them as derivatives.

Mr. M. C. Heys has in his collection an implement of this age which has been rechipped at a later period. It was found in the Swanscombe gravel of the 100-ft. terrace, and the contrast between the older work and the newer work is indeed striking. This implement is of the utmost importance, since it proves that the light brown staining and weathering was acquired between the manufacture of the implement and the deposition of the gravel in which it was found, and we are thus enabled to see how very much older these hill group implements are than the Palæoliths of the 100 ft. terrace. The implements from Ash and West Wickham have not only the same facies, but also the same mineral condition. They are nearly always of a light buff colour, though sometimes ochreous examples also occur, and at West Wickham a few examples are white. Some of them are abraded, and have evidently been derived from an older gravel, and in the process of derivation they have been greatly rolled, but by far the larger number are unrolled. Implements, and by this term we mean tools which have been made from a flint nodule, and not from a flake, are rare. The commonest type is the ovoid, sometimes twisted, and occasionally pointed, whilst the typical pointed implement so common in the 100-ft. terrace is rare.

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* 1889. J. Prestwich, "On the Occurrence of Palæolithic Flint Implements in the Neighbourhood of Ightham, Kent," *Quart. Journ. Geol. Soc.*, vol. xlv, p. 270.

Flake tools are common, and are of various shapes, hollo scrapers and rude side scrapers occurring not infrequentl Selected hammer stones are almost, if not quite, absent. Man of the flakes show the characteristic rectangular work which is t be found on the Eolithic implements. All the tools have bee made either from gravel flints or from the green coated flints fro the base of the Thanet sand. Some of the tools so greatl resemble the Eoliths in shape that it would appear as if attemp had been made to produce artificially the tabular flints so prize by the makers of Eoliths. It has often been asserted th scrapers are absent from these older Palæoliths; but, as we hav seen, this is quite contrary to our experience. This is only to b expected since scrapers are so abundant in the Eoliths. W venture to think that a careful examination of a large series the older Palæoliths will yield confirmation of the human origi of the Eoliths. Many of the flakes will be found to be worke back in exactly the same manner as the older implements. Th same hollow scrapers and double scrapers also occur. Ther can be but little doubt that much of the opposition which ha been offered to the Eoliths has arisen from a lack of knowledg of the older Palæoliths. It may be mentioned that true Eolith and transitional implements also occur with these hill grou implements, but their condition at once separates them an proves their derivative character.

Perhaps the most important locality from a stratigraphica standpoint is Swanscombe Hill, a good example of these olde Palæoliths being preserved in the Spurrell collection in the Natura History Museum. It is a rolled example, and undoubtedl belongs to the gravel. We can thus form some estimate of th antiquity of this implement from the fact that the highest terrac of the Thames is 180 feet lower. That is to say that since thi implement found a resting place in the Swanscombe Hill grave the Thames deepened its valley to that extent, and this highes terrace yields contemporary Palæolithic implements of the tru Acheuléen type. Probably this period is represented by some o the Ightham implements, but on this point it is impossible t speak with certainty.

IMPLEMENTS FROM THE DARTFORD GRAVEL TERRACE.

Unfortunately implements are extremely rare in this gravel There is one example in the British Museum found by Mr. F. C J. Spurrell, but this is possibly not a contemporary example, bu one derived from an older bed. Mr. W. W. Newton, however has a few from the same locality, and these are certainly later i type than the hill group tools, and approximate to the well known implements from the 100 ft. terrace, and on this ground i is better to class them with these latter until further research has added to our knowledge.

IMPLEMENTS OF THE SECOND TERRACE.

If implements are rare in the first terrace they are extremely common in the second terrace. The various pits in the neighbourhood of Swanscombe in this gravel have yielded an immense number, one collector having amassed over 80,000 examples. At Grays they are not uncommon, though in this district, as already noted, the men have no knowledge of flint implements, and the tools must be found by the collector. In the Ilford district they are also abundant. From their condition they readily fall into two groups, derived and contemporary. The former includes undoubted Eoliths, hill group implements, and a series which are intermediate between these older Palæoliths and the contemporary tools. These latter tools are by far the more abundant; occasionally they are patinated, but as a rule they are lustrous and stained. The implements and flakes, however, which occur in the upper part of the gravel at Swanscombe are either white or whitish. With regard to shape, the commonest form is the pointed tool, which varies greatly in size, and no doubt was used for various purposes. Many of these pointed tools, however, are really forms of the side-scraper. Four examples of this type are figured by Monsieur A. Rutot as "Coup-de-poing Chelléen,"* but they are undoubtedly side-scrapers. Ovoids are extremely rare, in this respect contrasting with the older Palæoliths where they are the most abundant forms. Trimmed flakes and scrapers of all sizes and shapes are common. Another noteworthy form is the so-called sling stones, and these are of all sizes and cannot have been used for the purpose which their name implies. The larger examples are perhaps cores or clusters from which flakes have been detached. The flakes are very often large, and are usually as broad or even broader than they are long. Perhaps no pit has yielded so many flint implements, considering the area excavated, as the small temporary pit opposite the Ingress Arms at Swanscombe where so abundant a fauna also occurred. In this pit side-scrapers were fairly common. Many of the implements from this pit were quite fresh, and exhibited no patina whatever. This was caused by the coating of carbonate of lime with which they were covered. Ignorance of this fact would lead one to suppose they were modern forgeries. It is well to note that implements of this age are practically always obtained from fluviatile deposits into which they have been introduced either by human or natural agencies. No instance is known to us of a working floor which has been

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* 1902, A. Rutot, "Etude Géologique et Anthropologique du Gisement de Cergy," Mem. de la Societé d'Anthropologie de Bruxelles, figg. 19, 20, 21, 22.

afterwards covered up which can be assigned to this period. Practically all the implements have been made from gravel flints, perhaps because there was little if any chalk exposed in any of the stream channels.

IMPLEMENTS OF THE THIRD TERRACE.

As we have already stated, a vast interval of time must have elapsed between the deposition of the second and the third terraces. The enormous physical changes which had occurred must indeed have taken a very long time. To excavate the main valley from the 100 ft. terrace to practically its present level is an operation whose magnitude it is difficult to realise unless one has carefully studied the matter in the field. Implements from this third terrace may be divided into two groups; first, those obtained from the old working floors which have been covered up by sand and brickearth; and, secondly, those obtained from the gravel. The latter are a very mixed group, but as a rule they are rare. They are not uncommon in one or two places at Grays, fairly common at Aylesford, and extremely rare in the wide spread of gravel which margins the river on both sides for some miles below London. Truly contemporary implements are extremely rare in the gravel, though we have seen two or three from West Ham in the collection of Dr. Corner, and a few have also been found at Aylesford. The majority have been derived from the middle terrace, but at Grays an intermediate series occurs. At Aylesford many of the implements belong to the hill group, and the rolling and bruising which they exhibit bears eloquent testimony to their derivative character.

The implements from the brickearths are a very homogeneous group. Four working floors have up to the present been found in our area, Stoke Newington, Grays, Crayford, and Swanscombe, whilst the few flakes from the Ilford brickearths are of this type, and it is quite possible that a floor existed there which has now been destroyed. Contrasting with what occurs in the 100 ft. terrace the material used was nearly always flints obtained directly from the chalk, the exposure of the chalk in the valleys now rendering this possible. Better material was thus available, and the implements show a great improvement on those of the second terrace. Perhaps the most characteristic tools are the long thin flakes, beautifully made, sometimes 8 in. in length, and as sharp as the day they were made. The secondary work is also very fine. It is, indeed, difficult to describe in words the characteristics of a group of implements. It can only be acquired by careful comparison, and this applies in the present case. The flakes are, however, much thinner and are, as a rule, much longer than they are broad. The tools are usually much better made, though, of course, it must be remembered that rude tools were used in all periods. It is remarkable how the worked flints from these floors all belong to the same group, and, except for slight differences in their condition, consequent on differences in the matrix, the tools from one locality are indistinguishable from those obtained from another floor. Judging from the figures the implements found by the late Mr. J. Allen Brown at Criffield Road, Acton, also belong to this group.*

IMPLEMENTS OF THE FOURTH TERRACE.

It is indeed a matter of regret that excavations in the fourth terrace are extremely rare, and implements from it are still rarer. We have noticed a few flakes at Grays, and Mr. W. J. Lewis Abbott has a small series from the Admiralty Section at Whitehall. These are all much smaller than those from the third terrace. In speaking of the Whitehall examples, Mr. Abbott says† : " But the most interesting of the flints were those that had been used by man ; of these there were some dozen plain flakes of various sizes, others were marked flakes of which one lanceolate form foreshadows the well-known Neolithic type. Although the quality of its work is essentially Palæolithic, some of the cores were very good, showing small parallel flaking. In others the flaking was much larger, and attained a length of three inches. All the worked flints from these gravels were deeply patinated, and some of the cores were water-worn." These implements certainly approximate to the cave implements of Solutre, the occurrence of one leaf-shaped example being indeed noteworthy.

LATER IMPLEMENTS.

In considering the later implements little stratigraphical evidence is available. It is curious how rare Neolithic implements and flakes have been in all the sections we have examined in the Holocene alluvium. Even the recent excavations for the new reservoirs at Walthamstow only yielded to our research a few flakes of no great interest. But a very large number have been obtained from the gravel dredged from the Thames ; and these cover a large period of time, judging by the differences in type. A large number greatly resemble the cave implements, whilst the more beautiful examples are probably of Bronze age. A recent discovery by one of us outside the area we are now dealing with, at Uxbridge, throws considerable light on the true position of some of these dredged implements. The discovery was made during an excursion of the Association in 1903.‡ At this place the gravel of the fourth terrace is largely excavated for ballast, the top of the gravel being about 6 inches above the water level,

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* 1887. J. Allen Brown, " Palæolithic Man in N.W. Middlesex."

† W. J. Lewis Abbott, "The Section Exposed in the Foundations of the New Admiralty Offices," *Proc. Geol. Assoc.*, 1892, vol. xii, p. 349.

‡ *Proc. Geol. Assoc.*, vol. xviii, pp. 188-9.

and it is covered by a thin deposit of Holocene shell marl an peat. The worked flints occurred on top of the gravel an beneath the alluvium. Here from an area less than an acre i extent, no less than 3,000 flakes and implements were obtained whilst a still larger number were rejected. These implement and flakes are identical with those found in the French caves o La Madelaine. They were made from chalk flints, the neares outcrop of which is two miles distant.

Many of the flakes were very large indeed, and all the tool exhibit great skill, scrapers were not uncommon, but were nearly a of the long duckbill type, only a few small ones being noted. On double scraper was found. This is a type which is fairly commo in the French caves, but it has never occurred to us with Neolithi tools. It should be noted that these flints are very similar to thos described by Mr. W. J. Lewis Abbott from the Hastings Kitche Middens and from Sevenoaks.* Recently, on examining the collection of Mr. M. C. Heys, at Swanscombe, we noticed a sma series of similar implements which we had obtained from Swanscombe Hill. In patination and work they differed so much fro the ordinary Neoliths, which also occur there, that it was quit easy to separate them. As to the exact age of this group, w cannot speak definitely. Judged by their general facies, they ar late Palæolithic and quite indistinguishable from the later cav implements. As to the Uxbridge find, all one can say is tha they must be later than the fourth terrace and earlier than th deposition of the alluvium. Mr. Abbott is of opinion that th Hastings and Sevenoaks implements are early Neolithic. In ou opinion the makers of this group of implements lived in thes islands for a considerable period of time, probably from lat Pleistocene to early Neolithic times.

We have been able to differentiate at least three other group of implements, *viz.*, the Rock Shelter implements, the Cissbur group and the ordinary Neolithic implements. For our knowledge of the Rock Shelter implements we are entirely indebted t Mr. Harrison, but it was Mr. F. C. J. Spurrell who first applie the term Rock Shelter to these implements from their resemblance to those from the Rock Shelters of France. They hav been obtained principally in the neighbourhood of Oldbury, an it is extremely probable from the nature of the rocks that tru Rock Shelters existed there in late Palæolithic times as they d to-day. It must be pointed out that the larger number wer found during excavations made at a little distance from th present rock face, and the inference is that there has been recession of the rock since the makers of these tools lived there Up to the present we have failed to find in any Thames deposi implements of this type. They are beautifully made, small, an as a rule ovate, but flakes and scrapers are also found. The

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* *Journ. Anth. Inst.*, 1895, pp. 124-145.

must be later than the third terrace, judging by their position in the scale of progress, and in all probability are either of fourth terrace age or they may be coeval with the excavation of the buried channel.

The Cissbury group is very well marked. They occur as a rule in isolated patches on the chalk hills. They are identical with those found at Cissbury. The flakes, as a rule, are large, much larger than the usual Neolithic; thick horse shoe scrapers are common, whilst hand choppers and true axes also occur. The true relation between this group and the ordinary Neolithic is well exhibited in two adjacent fields at West Wickham. In the one field, the Cissbury type is by far the most abundant, the flakes are always white and well weathered, but with them are a few implements and flakes of the Neolithic type. These are always much smaller, the flint is scarcely weathered, and the types are different. In the adjacent field the conditions are reversed. Here the most abundant tools are the ordinary Neolithic, small flakes and scrapers, and an occasional arrowhead patinated and not weathered, with a few implements of the Cissbury type, and these latter are always weathered, while as additional proof implements occur which are "Cissbury" tools reworked, and in these the newer fractures are always lustrous and black, and thus we are enabled to see that there must be a vast difference in time between these two groups. It is just possible that what we call the Neolithic tools are really of Bronze age, or even early Iron age, but there are no facts to warrant such a conclusion. We have thus in the Lower Thames Valley the following groups of implements:

1. Eoliths.
2. Transitionals.
3. Older Palæoliths.
4. Palæoliths from the 100 ft. terrace.
5. Palæoliths of the brickearths.
6. Palæoliths of the fourth terrace.
7. Rock Shelter implements.
8. Implements of the Uxbridge type.
9. Cissbury implements.
10. Neoliths.

Of these, Nos. 1, 3, 4, 5, 6, have a true stratigraphical value, whilst the position of 8 is partly settled. The sequence of the remainder is a matter of inference from their position in the scale of progress.

CONCLUSIONS.

We have endeavoured to show that it is possible to divide the history of the Lower Thames Valley into several stages, and that these stages can be used in the classification of flint implements. Though, from its nature, such a scheme can only be local in its application, yet it is possible that a correlation may be made with the implementiferous beds of other river systems, and also of the Continent. In Belgium during the past few years an enormous advance has been made in the knowledge of primitive man, an advance which is due to the knowledge and enthusiasm of Monsieur A. Rutot. Numerous papers have been written by him, and he has also drawn up an elaborate system of classification, and an extremely interesting comparison of the various stages in Belgium, England, and France.* Unfortunately, Monsieur Rutot's personal knowledge of the geology of the south-east of England is limited to a flying visit of a few weeks duration, and we venture to think that a further acquaintance with the drift geology of this country would materially alter his views. Misled by the occurrence of *Elephas antiquus* at Crayford, he has placed the brickearths of that place earlier than the Chalky Boulder Clay, and much earlier than the 100 ft. terrace; whereas, as we have seen, the implements which occur at the base of the brickearths, and which are undoubtedly contemporary, belong to a much later stage than the 100 ft. terrace implements. Thus we have a further instance of the errors likely to arise when only Palæontological evidence is considered. It is possible that on the Continent *Elephas antiquus* may mark an earlier horizon than *E. primigenius*, but it does not apply in England. It will be remembered that Professor Boyd Dawkins was led into a similar error, also through Palæontological evidence. On this point the stratigraphical evidence is clear, the brickearths of Crayford and Grays are much newer than the 100 ft. terrace. Monsieur Rutot considers the Eolith of the Chalk Plateau to be the earliest traces of man, and to be of the same age as the Walton Crag. It is quite possible that some of the Plateau Gravels may be of this age, but as we have seen, the deposition of these gravels extended over a very long period, so it is probable that some of them may be contemporary with the Crag of Butley or the Norwich Crag, or even the still later Weybourne Crag.

The second stage of the Belgian savant is the Forest-bed, where implements have been obtained by Mr. W. J. Lewis Abbott and Mr. Shrubsole. Judging from the implements we have seen, they are identical with those which we have described as transitional between the Eoliths and the Hill Palæoliths. Thus far we agree with the sequence of Monsieur Rutot. His third stage is a Belgian one, the so-called *industrie reutellienne*, which he considers to be of the same age as the Lower Boulder Clay. Judging from his figures, and from those examples which we have seen, this group is the same as our Eoliths; whilst his next stage, *industrie reutelo-Mesvinienne* is in our opinion identical with the transitionals. There has probably been a duplication here.

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* A. Rutot "Esquisse d'une comparaison des Couches Pliocene et Quaternaires, etc." *Bull. Soc. Belge de Geologie*, 1903, vol. xvii, pp. 57-100 and table.

Unable to correlate the two earliest Belgian stages with the two earliest English he has considered them as separate, whereas they are identical.

His next stage, the *industrie mesvinienne*, which he correlates with the Crayford brickearths and the Middle Glacial sand, is undoubtedly equivalent to the earlier of that composite group, the Hill Palæoliths. Whilst the two next stages, *transition du mesvienien au chelléen* and the *industrie chelléenne*, would represent later periods in the same group. His next stage, the *acheuléenne*, is one over which there is no dispute. This is the equivalent of our 100 ft. terrace, and there can be no doubt that the implements of St. Acheul are contemporary with those contemporary tools which occur so abundantly at Swanscombe.

In nearly all the Continental schemes of classification the next stage is the Mousterian, though it is ignored by Monsieur Rutot. The typical locality is the cavern of Le Moustier, Dordogne, France, which is generally considered to be the oldest of the French caves, though later than the Acheulian. Though it is the oldest of the French caves, it is extremely probable that the implements from the Breccia (the lowest bed) of Kent's Cavern, as well as those from the lowest bed in Robin Hood's Cave, Derbyshire, and those from Pontnewydd Cave, North Wales, are quite as old as our 100 ft. terrace implements, even if they are not older. In our district we have a group of implements which are very similar to those from Le Moustier, namely, the implements from the Palæolithic floors at Crayford, Grays and Stoke Newington. This identification was first made by Mr. Worthington G. Smith, and in our opinion is a correct one.

The remaining Palæolithic stages are derived from French caves, and have a true stratigraphical nature, namely, the *solutréen* and the *magdalénien*. It is extremely difficult to correlate our later stages with either of these. The former may represent our fourth terrace, and the Rock Shelter implements of Ightham, and there are strong reasons for so placing them, whilst the "*magdalénien*" implements are identical with those found at Uxbridge. As we have already stated, our classification is a local one, though since it deals with the principal river in England, and an area where the complete sequence is best preserved, it is deserving of considerable attention. We would therefore suggest the following classification for the pre-Neolithic:

1st. Eoliths.
2nd. Transitionals.
3rd. Hill Palæoliths.
4th. Acheulian Implements.
5th. Mousterian.
6th. Rock Shelter or Solutréen.
7th. Magdalénian or Uxbridge type.

Practically all these are stratigraphical divisions, and th exhibit a fairly complete scale of progress. There are no break The Eoliths grade into the Transitionals, which, in their tur pass into the older Palæoliths. These are not marked off by strong line of demarcation from the 100 ft. terrace implement The Mousterian implements of the brickearths are obviously development of their immediate predecessors, whilst the Roc Shelter tools are a still further development, and form a connec ing link between the Mousterian and the Magdalénian. Ne types occur at various horizons, but always accompanied by th older types so as to conclusively prove that we are dealing wit an ascending scale of progress.

The last stage, the Magdalénian, apparently lasted well int the Holocene period, judged by Mr. Abbott's discoveries in th Hastings Kitchen Midden and at Sevenoaks. The two remaining groups we have noted are extremely difficult to deal with. The "Cissbury" implements form a decided group; undoubtedly later than the Magdalénian, they do not stand so high in the scale of progress, and their general facies leads one to suppose that we are dealing with the handiwork of another race. Fa more accurate work must be done to this subject in the future than has been done in the past, before we shall be able definitely to settle the true relations between the "Cissbury" implements and those implements which, for want of a better name, we have called "Neoliths." The result of our researches leads us to place the Cissbury type early in the Holocene period, whilst the latter group may well mark the later stages of the polished Stone age the Bronze, and even the early Iron age. Certain it is that our most beautiful implements, the exquisitely ground and polished axes, gouges and skin dressers, are not earlier than the Bronze age. We do not pretend for one moment that we have exhausted the subject, even in our own limited area. If there is one fact more than another that has been impressed on our minds, it is how little we really know about this subject. We have ventured to express our views in the hope that other students will turn their attention to this field of research, and thus add to our limited knowledge of Pre-historic Man.

PLATE I

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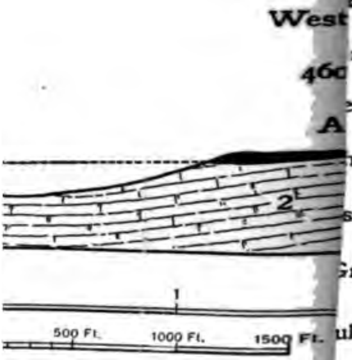

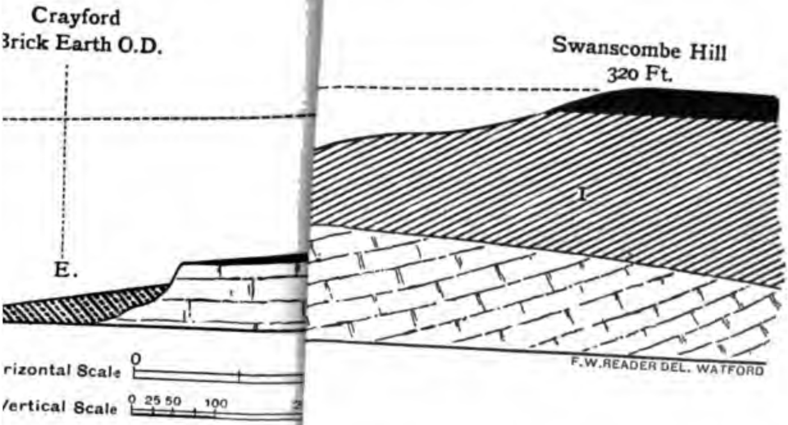

M. A. C. Hinton & A. S. Kennards' paper, pp. 76-100.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

MARCH 11TH, 1905.

Directors: THE PRESIDENT AND DR. C. W. ANDREWS, F.G.S.

(*Report by* THE PRESIDENT.)

A PARTY of about sixty members were received by the Directors in the Central Hall, and proceeded to the Gallery of Fossil Mammalia, where Dr. Andrews explained the newly-arranged cases of primitive elephants. He pointed out how the diminutive *Mœritherium* of the Middle Eocene of Egypt passed into the larger *Palæomastodon* of the Upper Eocene of the same country. The latter animal showed for the first time the reduction of the front teeth to a pair of tusks in each jaw, the upper tusks curving freely outwards and downwards, the lower tusks at the end of a long chin working against a pad on the palate. The long chin was formed by the elongation of the bony symphysis of the mandible, and the soft face and snout above it were not strengthened by bone. *Palæomastodon* was followed by the still larger *Tetrabelodon*, which lived in the Miocene period both in the Old World and in North America. In the Pliocene period the true *Mastodon* arose by the sudden loss of the long, bony chin and the consequent fall of the soft face into a hanging proboscis or trunk. Finally, came the true elephant by stages often described in text-books.

Dr. Andrews also called attention to the skulls and other remains of the remarkable *Arsinoitherium* found with *Palæomastodon* in the Upper Eocene of Egypt. This animal seems to represent a sub-order of horned hoofed animals closely related to the ancestral elephants.

Among other newly exhibited fossil mammals, the President next referred to a large collection of remains of the extinct ground-sloth, *Grypotherium*, from the well-known cavern near Last Hope Inlet, in Patagonia. The freshness of the skin and bones was noteworthy, but the President thought they were proved to belong to a remote pre-historic period, and had been preserved under exceptional circumstances in dry earth. There was no longer any hope of finding *Grypotherium* alive.

After the demonstration Mr. G. C. Crick exhibited to the party a newly-acquired plaster cast of the largest known ammonite, 6 ft. 8 in. in diameter, from the Upper Cretaceous of Westphalia. The original specimen is in the Provincial Museum at Münster, and has been described under the name of *Pachydiscus seppenradensis.*

VISIT TO THE ZOOLOGICAL SOCIETY'S GARDE

MARCH 18TH, 1905.

Director: DR. P. CHALMERS MITCHELL, M.A., Sec. Z.S.

(*Report by* THE DIRECTOR.)

THE first outdoor excursion of the season took place on Sat day, March 18th, when fifty-four members and friends visit the Zoological Gardens in Regent's Park. The Associati assembled at the main gate at 3 p.m., where they were m by Dr. Chalmers Mitchell, the Secretary of the Zoological Societ who acted as Director. The party first visited the Monk House, where the lemurs, now displayed in a large central cag attracted special attention. A move was then made to t Anthropoid Ape House, where Dr. Chalmers Mitchell gave short address on the characters and distribution of the livi Anthropoid Apes, pointing out the variations in the chimpanze from different parts of Africa, many races being distinguishab Two of the young chimpanzees were brought out to shake han with the visitors. On leaving the Ape House the Geologi inspected the artificial mass of rocks being erected at the n Sea-Lions' Pond. Passing through the Lion House, wh attention was directed to the value of the new green paint the back of the dens as a more suitable background for display of the colouration of the animals, the party moved on the Reptile House. There special attention was directed to specimens of *Hatteria*, the so-called Tuatera Lizard, wh probably represents a distinct Order of Reptiles, and the p were reminded of the wide distribution and varied nature its numerous relatives in past geological epochs. Of m interest also were the examples of the Australian Lung-F (*Ceratodus*), the first specimens that had been alive in country since the Jurassic period. The next visit was to New Small Mammal House, where a special object of inte was a Tasmanian Thylacine, now a rare animal, which is clos related to the carnivores characteristic of the Eocene period, a to the Old Small Cats' House, now repaired and arranged small mammals such as squirrels. After admiring the Sn Leopard in its out-door cage, the party crossed the canal to t Insect House, in which, at the present time, no fewer than thr species of living Birds of Paradise are to be found. The natives of the Malay Archipelago, notwithstanding their gorgeo plumage, were stated by the Director to be near allies of t Crows and Ravens (*Corvinæ*). The Association next visited t Canal Bank Aviary, a large out-door erection of wirework finish in 1904. It was occupied by a large number of Macaws, Parro

Cockatoos, and Parrakeets, which had abundant room to fly about. Dr. Chalmers Mitchell stated that although the majority of these birds had been in the Aviary throughout the winter, with no artificial heat and with no other shelter than a number of nesting-boxes, the rate of mortality had been very low, lower indeed than that in the artificially-heated Parrot House, and that the general health of the birds had been extremely good. He pointed out that people were too much inclined to suppose that because creatures were now found in the Tropics a tropical climate was necessary to their existence or comfort, and suggested that Geologists should not be too rash in ascribing a warmer climate in past times to any particular region because of the presence of fossil remains of creatures now tropical in their habitat.

After a vote of thanks had been given to Dr. Chalmers Mitchell on the motion of Dr. Smith Woodward, the President of the Association, the party dispersed, many of its members visiting the Gardens in more detail.

EXCURSION TO SHOOTER'S HILL, BLACKHEATH, AND LEWISHAM.

SATURDAY, MARCH 25TH, 1905.

Directors: A. E. SALTER, D.Sc., F.G.S., and A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTORS.)

ON arriving at Well Hall Station the party, numbering 35, proceeded to Shooter's Hill, and, on reaching the stile at Castlewood, the main features of the landscape were pointed out, and the presence of London Clay noted in some small exposures. Reference was also made to the many items of historical interest connected with Shooter's Hill, and the mention of it by Lord Byron in one of his works.

By the kindness of Probyn Godson, Esq., the grounds of Castlewood House were entered, and a small gravel pit, by the side of the path leading to the Bull Inn, was investigated. This is several feet below the summit of the hill, and the gravel has probably been derived from the higher deposits at the top. It was pointed out that it was to the presence of this capping of gravel that Shooter's Hill had been preserved, whereas the London Clay strata all round had been denuded away.

The party then proceeded to Severndroog Castle, which was erected in the eighteenth century as a memorial of the capture of the Severndroog pirates on the Malabar Coast of India, by Sir William James in 1755.

The views from the top are exceedingly fine. On a clea day Windsor Castle can be seen, and by the aid of glasses th Chiltern Hills, above Nettlebed, beyond.

The gravel pits beyond the Bull Inn, and to the east c Shrewsbury Lane, were next visited. These are situated close t the highest point, and are about 424 ft. O.D. Mr. F. C. G Spurrell described the gravel in 1886 (*cf.* references).

It was found to consist almost entirely of Tertiary flin pebbles. Among other rocks more rarely found may b mentioned subangular flints, quartz pebbles, jasper, ironston and dark chert, with secondary quartz veining, all of whic might be derived from the south. Lower Greensand Chert fro the Hythe Beds of the Wealden area does not appear t occur.

Mr. B. Polkinghorne, B.Sc., exhibited on behalf of himse and Mr. A. P. Leach a series of Neolithic implements obtaine on the surface of the hill, also a Modiola Sp. (? Elegans), Corbul Sp., and a piece of selenite from the London Clay below th gravel.

Reference was made to the Mineral Well on the N.W side behind the Eagle. Time, however, did not allow th party to visit it. It is mentioned by Evelyn in his diary 1699.

Proceeding towards Blackheath a small section in th Blackheath Beds, close to Morden College (built in 1695), wa examined. Between this section and the College is a smal valley which is now dry. This is the upper part of the sam valley in which the sections at Belmont Hill, Lewisham, ar situated.

Passing along the south side of Blackheath and down Lov Lane to Belmont Hill, by the kindness of Messrs. H. and G Taylor, the party investigated an interesting series of section showing Thanet Sand, and Woolwich and Reading Beds in whic the Shell Beds had been well exposed. The latter beds wer covered by an interesting recent gravel and clay deposit, whic showed good evidence of hill creep, but owing to the heavy rai of the previous week they were not in good condition.

There was about 17 ft. of Thanet Sand exposed, above whic was 4 ft. of green sandy clay containing pebbles, showing th irregular junction with the Thanet Sand; above this 3 ft. of yellowis sandy pebbles, then 3 ft. of hard red clay with pebbles apparentl representing the mottled clay of other sections; then followed 3 ft of a yellowish sandy pebble-bed, and 2 ft. of cyrena shell-bed wit a thin oyster-bed at the top. Above this was, in the upper of th two sections, 10 ft. of gravel, which in some places cut into an was thrust under the shell-bed. At the base of the shell-bed som very hard flinty "race" was found, which on analysis by Mr. H Dixon Hewitt, gave the following composition :

Calcium Carbonate ($CaCO_3$)	94·7
Magnesium Carbonate ($MgCO_3$)	0·7
Iron and Aluminium Oxides ($Al_2O_3 + Fe_2O_3$)	3·0
Sand and Clay	0·6
Combined Water, traces of Alkalis, Phosphates, etc. (by difference)	1·0
	100·0

A sample of the red clay was also analysed by Mr. Hewitt, th the following result:

Ferric Oxide (Fe_2O_3)	7·1*
Hygroscopic Moisture	9·8
Loss on Ignition (not including hygroscopic moisture)	4·7

GENERALIZED SECTION OF THE TWO PITS ON SOUTH SIDE OF BELMONT HILL ESTATE.

	ft.	in.
Drift	10	0
Cyrena Bed with clay partings (shells mud-broken)	2	3
Yellowish clayey pebble bed	3	0
Indurated crimson clay with pebbles	3	0
Yellow sandy pebble bed	3	0
Dark green clayey sand with pebbles with irregular junction with Thanet Sand below	4	4
Thanet Sand	17	0
	42	7

In the lowest part of the estate, beneath the site of an old nd, a deep excavation had been made, and a fine example Drift exposed some 15 ft. thick. Much discussion ensued its precise mode of origin, but it was felt that to decide this relation of the Thanet Sand below to the Chalk needed to be de out. It was composed largely of Tertiary pebbles and d with some subangular flints, and appeared to have been posited tumultuously.

IFT SECTION IN RIVER VALLEY AT THE FOOT OF THE HILL JUST SOUTH OF THE SOUTH-EASTERN RAILWAY.

	ft.	in.
Contorted gravel and sand with occasional clayey patches	6	0
Unevenly bedded Drift, principally made up of Woolwich and Blackheath pebbles, with subangular flints	9	0
Thanet Sand	15	0
	30	0

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* Iron (Fe) 5·0.

If there has been no sinking of the Thanet Sand from solution of the underlying Chalk, the total thickness of Thanet Sands exposed in the three sections would be 42 ft., and as the greatest thickness in that district has been given as 50 ft., the Chalk should be reached within 10 ft. Messrs. Taylor have kindly promised to put a boring down to prove this.

The Upper Beds of Drift seem to have been laid down tumultuously, many of the pebbles being on end. A large green quartzite pebble from the Blackheath Beds was found, but no other "foreign" rocks were observed and no trace of the overlying shell beds.

The lower part of the Drift is unevenly bedded, but shows signs of stratification. Near the base occur streaks of black sand, an analysis of which, by Mr. H. Dixon Hewitt, gave the following result:

Sand	85·5
Manganese dioxide (MnO_2)	8·0
Iron and Aluminium Oxides (Fe_2O_3 + Al_2O_3) .	2·1
Loss on Ignition	4·4
	100·0

This river-valley seems to have been the principal drainage system from the high ground round Blackheath and Shooter's Hill towards the Ravensbourne at Lewisham, but the head of the valley was subsequently cut off by the present river Quaggy, which flows by Kidbrook and Lee to Lewisham.

The members of the Catford Natural History Society had paid much attention to these sections, and the Secretary, Mr. W. H. Griffin, exhibited some fine full-plate photos taken when the sections were at their best. Mr. Hewitt, the Registrar, had also made the above chemical analyses:

Those members who did not proceed at once to London took tea at Till's Restaurant near the Obelisk, Lewisham, where a hearty vote of thanks was accorded the Directors, who suitably responded.

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——. W. T. VINCENT.—"Records of the Woolwich District."
1891. "Records of Excursions," pp. 4-8.
1905. A. E. SALTER.—"On the Superficial Deposits of Central and Parts of Southern England." *Proc. Geol. Assoc.*, vol. xix, p. 8.

See also *Quarterly Journal of the Geological Society*, vol. ix, p. 290 and Plate XIII; vol. xxxviii; Plate XXVI; vol. xliv, Plate V.

Since the above excursion there has been a new road cut from Well Hall Station to Eltham Church, giving a very interesting section in Blackheath Beds, which rise from under the London Clay which has been exposed close to the railway bridge. There is exposed about 5 ft. of shell-bed, the upper part very much decalcified in parts, giving the shell-bed the appearance of a series of crags surrounded by the pebble bed. The oyster bed has been much indurated along one or two horizons, and some very good specimens can be obtained. The following fossils have been found by our members: *Odontaspis elegans* (abundant), *Phyllodus* (two species), *Otodus obliquus*, *Carcharadon*, Vertebræ of Shark, *Ostrea bellovacina*, *O. tenera*, *Modiola*, *Cerithum*, etc.

Being only a temporary section an early visit is advisable.

EXCURSION TO GERRARD'S CROSS, BUCKS.

SATURDAY, APRIL 1ST, 1905.

Director: R. C. SIKES, B.A., M.Inst.C.E.

Excursion Secretary: A. H. WILLIAMS.

(*Report by* THE DIRECTOR.)

ON reaching Uxbridge Station the party of twenty-two members and friends walked in a northerly direction along the bank of the Grand Junction Canal, to the point at which it is crossed by the new G.W.R. and G.C.R line, and then followed the railway westwards to Gerrard's Cross. The first cutting passed through was that at Doggett's Farm, where the section is similar to that afterwards examined at Gerrard's Cross, but is not so well exposed. The long cutting at Gerrard's Cross, through the high ground to the west of the River Misbourne, showed the following general section from the east end to the centre of the cutting:

		ft.		ft.
1. Plateau Gravel (sand and gravel) . .	from	16	to	25
2. London Clay (dark grey and brown sandy clay)	about			5
3. Reading Beds (blue and mottled clay) . . .				15

The section at the west end of the cutting was as follows:

		ft.		ft.
1. Gravel		5	to	15
2. White, brown and green sands				12
3. Clay, with flints at base	about			1
4. Chalk (visible in bottom of cutting)				

A few teeth were found by the party in the London Clay band, and some characteristic London Clay shells, mostly in a bad state of preservation.

Attention was drawn to the fact of the London Clay band displaying abrupt changes in thickness in places, and to its not being quite continuous up to the centre of the cutting, as in one place the gravel was seen to rest directly on the Reading beds. It was suggested that these peculiarities were perhaps due to the London Clay band having been re-deposited, and to its not being strictly "in situ." The large number of quartzites in the gravel was noted, while near the west end of the cutting some sarsens were examined, a few being seen in place projecting from the side of the cutting. One large block lying in the bottom of the cutting measured 4 ft. by 2 ft. 3 in. by 2 ft. Many truck loads of sarsens were removed during the construction of the railway; they were usually found in the white and brown sand, a few in the gravel, but none in the green sand (see section at W. end of cutting given above).

Tea at "The Bull" was very welcome after a somewhat long walk, and the party then drove to Uxbridge Station *en route* for Paddington.

REFERENCES.

Geological Survey Map, 1 inch, Sheet 7.

Ordnance Survey Map, 1 inch, New Series, Sheet 255.

1889. Whitaker, W.—"Geology of London," vol. i, *Mem. Geol. Survey.*

1895. Brown, J. Allen.—"Notes on the High-level River Drift between Hanwell and Iver." *Proc. Geol. Assoc.*, vol. xiv, p. 153.

1897. White, H. J. Osborne.—"On the Origin of the High-level Gravels with Triassic Débris adjoining the Valley of the Upper Thames." *Proc. Geol. Assoc.*, vol. xv, p. 157.

EXCURSION TO WELWYN, HARMER GREEN AND DATCHWORTH.

April 8th, 1905.

Director: A. E. Salter, D.Sc., F.G.S.

(*Report by* The Director.)

Leaving King's Cross (G.N.R.) by the 2.30 p.m. train, the party, numbering 25, arrived at Welwyn at 3.9 p.m., and immediately started in a N.E. direction towards the Tertiary outlier upon which Harmer Green and Burnham Green are situated. The outlier owes its preservation to a capping of gravel, and a section in the gravel was first investigated in Mr. Powell's pit, which lies in a field to the left of the road at about 409 ft. O.D. The depth of the section varies from 5 to 10 ft., and shows a stratified gravel with false-bedded sand below in one part of the pit. The upper part was disturbed, and in places contained many pebbles with their long axes vertical.

The gravel was made up of Tertiary flint pebbles, subangular flints, quartz pebbles of various kinds, rough quartz blocks to 4 in. long, light coloured quartzites, banded rhyolite (some much decayed and apparently spherulitic), jasper, grits, Herts Conglomerate, dark chert, etc.

The non-local material is chiefly of a Palæozoic character. Jurassic material, Bunter pebbles, Basalt and Granite appear to be absent. The Director pointed out that the gravel occupies rather a high position in the "Drift Series" connected with the Stevenage Gap, and stated that southern Hertfordshire and northern Middlesex were formerly the meeting-ground of old streams from the north through the Stevenage Gap, from the west, *viâ* Goring Gap, and from the south; these uniting to form an easterly-flowing stream across Essex.

At and near the Duck Inn, Burnham Green, boulders of Sarsen and Herts Conglomerate were seen.

The next section visited was the larger pit (Holtens) to the north of Datchworth Church. This is upwards of 10 ft. in depth, and shows lines of stratification well, except where it is disturbed owing to piping in the chalk which lies immediately beneath (*c.f.* previous pit). Sandy and clayey patches are frequent.

The gravel consists chiefly of flints (Tertiary pebbles, green-coated, etc.). Two unworn flints were seen over a foot long and broad, Bunter Quartzites, Quartz, Herts Conglomerate, and Sandstone. Jurassic material, Basalt, Granite, etc., were not seen.

This deposit is below the 400 ft. O.D. contour line, and occupies a lower position in the Drift Series than the gravel at Harmer Green. It differs also from it in containing much Triassic material.

Pits were seen in similar gravel on either side of the railway line at Woolmer Green, but time did not permit an examination of them.

Tea was taken at the Cowper Arms Hotel, near Welwyn Station, and then, after passing a hearty vote of thanks to the Director, the party returned to London by the 6.44 p.m. train.

REFERENCES.

Geological Survey Map, Sheet 46 S.E.

1889. WHITAKER, W.—"Geology of London."

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1905. A. E. SALTER.—"The Gravels of Hertfordshire." *Trans. of the Herts. Nat. Hist. Soc. and Field Club*, vol. xii, p. 137.

EXCURSION TO FLITWICK AND SILSOE.

SATURDAY, APRIL 15TH, 1905.

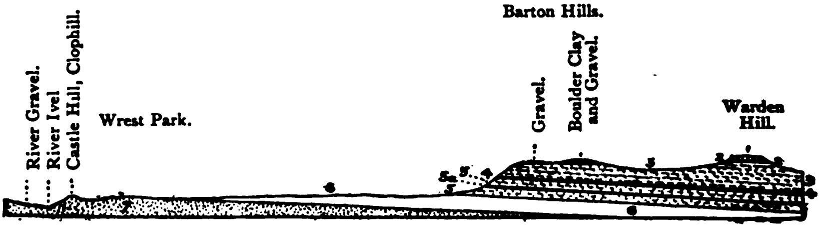
Directors: JOHN HOPKINSON, F.L.S., F.G.S., Assoc. Inst.C.E., and JAMES SAUNDERS, A.L.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* MR. HOPKINSON.).

IN the journey from London, after leaving Middlesex for Bedfordshire, the whole of the Upper Cretaceous strata represented in the section was passed through, and in the cuttings of the Midland Railway between Chiltern Green and Charlton the three hard beds in the Chalk—the Chalk Rock, the Melbourn Rock, and the Totternhoe Stone—were seen. On the plain beyond, the Gault was traversed, and in approaching Flitwick the outcrop of a formation better withstanding denudation—the Lower Greensand—became evident from the rising ground. The Chalk on the south, attaining a height of 800 ft., and the Lower Greensand passing through the centre of Bedfordshire, rising to 500 ft., form the two main ranges of hills in the county, and the object of this meeting was to examine sections of the latter formation.

SECTION, NEARLY NORTH AND SOUTH, FROM CASTLE HILL, CLOPHILL, TO WARDEN HILL, NEAR LUTON.—*J. Hopkinson.*



Horizontal scale 1 in. to 2 miles; vertical scale 1 in. to 2,000 ft.

1. Upper Chalk.
2. Chalk Rock.
3. Middle Chalk.
4. Melbourn Rock.
5. Lower Chalk.

5*a*. Totternhoe Stone.

6. Gault.
7. Lower Greensand.

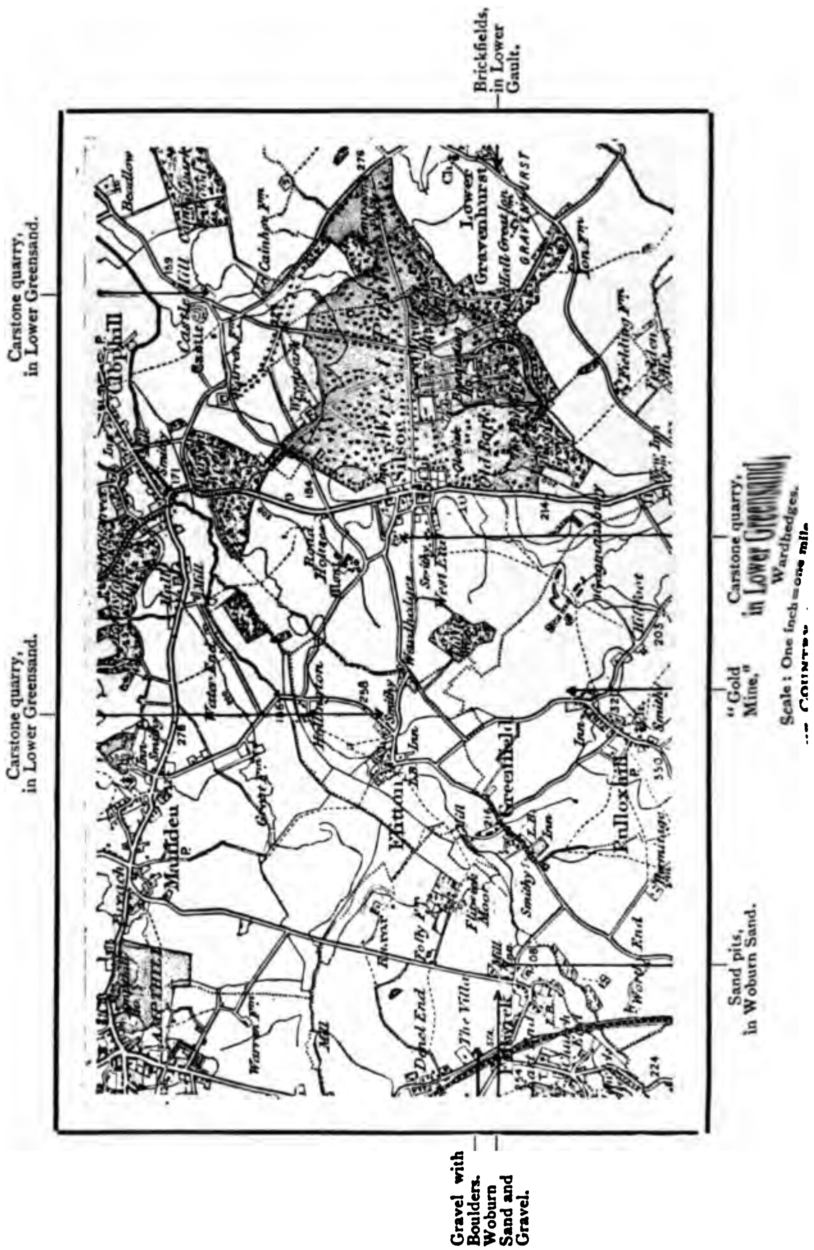
A party of sixteen assembled at Flitwick Station. A good section of the Woburn Sand, with its variously-coloured beds, from white to red, was seen near the railway, on the west of the line; its position appears to be about the middle of the Greensand. On the opposite side of the line, north of the station, the ground is a little higher, and the highest part is capped by a bed of gravel and sand (now being removed for road-metal and garden-paths), containing boulders apparently derived from the higher part of the Greensand, which has here been eroded away, and rocks of foreign origin drifted from Palæozoic beds in the north.

Descending into the valley of the Flit, other sections of the Woburn Sands were seen, and the party then divided, the walkers, under the guidance of Mr. Saunders, crossing Flitwick Moor to Flitton and Wardhedges Quarry, Silsoe, and the cyclists, conducted by Mr. Hopkinson, taking the road through Greenfield and Flitton to the Castle Hill Quarry, Clophill.

Mr. Saunders reports: "The walking party visited the source of the Flitwick mineral springs. Most of the members tasted the water, which had been filtered, and it was found to be strongly impregnated with iron and vegetable acids. It has powerful medicinal properties, chiefly tonic and astringent. After passing Greenfield Mill the course led by the side of the River Flit. It was noticed from the appearance of the water that it contained iron, which was being deposited on the pebbles in the brook. It was very unlike the bright, sparkling streams which pass through the chalk district of the south of the county."

On their way to Castle Hill the cyclists visited Flitwick Quarry, where the "Carstone" of the Lower Greensand is exposed. This is on a higher horizon than the Woburn Sand, and, like it, shows current-bedding, or perhaps in its case more correctly false-bedding. The section at Castle Hill exposes the same and the succeeding beds to the highest portion of the Greensand seen in this neighbourhood. It is of special interest, as it shows 10 ft. of dark-coloured clay, called by the workmen "black clay," to distinguish it from the "blue clay" of the Gault, occurring in three distinct beds of about equal thickness with thin layers of sand between them, dark-red carstone being above the clay, and light-coloured sand beneath it. This black clay occurs at Shefford, to the east, where it has thinned to one foot, but it is not known to occur elsewhere. It is used by the workmen at the brickfields at Lower Gravenhurst, which would have been visited had time permitted, to mix with the clay there obtained from the Lower Gault. The face of the quarry in which the layers of clay are seen, looks towards Castle Hill, and does not show cross-bedding, but behind these workings there is another quarry showing the sand and carstone apparently without the clay, and very much cross-bedded. In it, capping the Greensand, there is a thin bed of chalky boulder clay, in which drifted specimens of *Gryphæa incurva* were found. The "doggers" and harder layers in the Greensand are here being quarried for the new waterworks at Biggleswade.

The two parties then joined forces at the George Inn, Silsoe, where a good tea was provided, after which the walkers returned direct to Flitwick, and the cyclists visited Wardhedges Quarry, an extensive excavation in the carstone, showing well the doggers of harder rock which owe their hardness to the infiltration of iron,


Carstone quarry, in Lower Greensand.
Carstone quarry, in Lower Greensand.
Brickfields, in Lower Gault.
Sand pits, in Woburn Sand.
"Gold Mine,"
Carstone quarry, in Lower Greensand, Wardhedges.
Scale: One inch = one mile.
Gravel with Boulders.
Woburn Sand and Gravel.
Ampthill
Maulden
Flitton
Silsoe
Greenfield
Pulloxhill
Clophill
Lower Gravenhurst
Wardhedges
Flitwick Moor
Denel End
Water End
Beadlow
Cainhoe Fm.

l also fine examples of cross-bedding. This quarry had been viously examined by the walking party. The cyclists then ted the site of the historical "gold mine" in Gold Close, llox Hill. Some account of this mythical mine had been en by Mr. Hopkinson after tea, before the party separated. It well known to the villagers—apparently by tradition—he had nd on inquiry, that a furnace had been set up and gold was l to have been obtained, and notices of the occurrence of gold e occur in various works. Calvert, in his *Gold Rocks of Great itain* (1853), mentions it on the authority of Waters' *Com-dium of British Mining* (1843), where the following passage urs: "About 160 years since, two gold mines were stated to e been discovered; one at Pollux Hill, in Bedfordshire, and other at Little Taunton, in Gloucestershire. The Society of nes Royal seized them, and granted two leases of them to ne refiners, who extracted some gold; but they did not go on h the work, as the gold sometimes would not repay or requite charge of separation, though sometimes it did." Watson's tation is from Abbott's *Essay on the Mines of England.* This about the year 1640; in the eighteenth century there was a ort that gold had again been found near Ampthill, and it ms to have caused some excitement. Pennant, however, es that it "turned out nothing but talc."

In the original Ordnance Survey Map the name of the adow, "Gold Close," is not only given, but the actual site the mine is located by the words "gold mine," while in the r series both these indications of the site are omitted, a revision ch to be deprecated.

The cyclists rejoined the walkers at Flitwick in good time for appointed train. The weather was perfect, and the country, ich in the neighbourhood of Clophill is very pretty, had the hness of the spring with a foretaste of the leafiness of the nmer.

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EXCURSION TO MID-LINCOLNSHIRE, EASTER, 1905.

FROM APRIL 20TH TO 26TH, 1905.

Directors: Prof. P. F. KENDALL, F.G.S., HENRY PRESTON, F.G.S., Rev. W. L. CARTER, M.A., F.G.S., and Rev. E. NELSON, M.A.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report of the Grantham and Lincoln visit by* HENRY PRESTON, F.G.S.)

THE principal object of the Easter Excursion, 1905, was to investigate the Geology of Mid-Lincolnshire, and included the districts around Grantham, Ancaster, Lincoln, Louth, Market Rasen, and Claxby.

On Thursday, 20th, some early visitors reached Grantham at 4.22 p.m., and accompanied Mr. Preston south of the town to see exposures of Upper Lias Clay and Plateau Gravel.

The Upper Lias in this district consists of a dense blue-grey clay with bands of septarian nodules. These clays comprise the zones of:

Leda ovum, with *Am. bifrons*,
Am. communis,
Am. serpentinus,
The paper shales,

and have a total thickness of about 120 ft.

The clay was first seen in Rudd's Brickyard, and a very interesting band of nodular ironstone was examined, which occurs at the top of the fossiliferous zone of the *Communis* beds, and contains numerous dwarfed specimens of Ammonites of the various zonal types. The bed is filled with oolitic grains averaging about $\frac{1}{16}$ in. diameter, which often show a beautiful banded structure when mounted for the microscope. The chief feature, however, is the number of species of gasteropods which this concretionary bed contains, as will be seen from the following in Mr. Preston's collection:

Pleurotomaria perseus, *Pleurotomaria* sp., *Onustus Spinosus*, *Turbo Theodori*, *Cerithium costellatum*, *Cerithium armatum*, *Cerithium* sp., *Fusus* (?), *Alaria* sp., *Amberleya capitana*, *Turritella* sp.

When passing over the fields to the Great North Road a good general view was obtained of the great escarpment of Lincolnshire Oolite Limestone known as the Lincolnshire Cliff, which has practically a north and south strike through the whole county.

The gravel pit on the east side of the North Road just S.W. Little Ponton was next visited. The gravel consists of nded and smoothed pebbles of Inferior Oolite, Liassic nestones, Marlstone, Carboniferous Limestone, and Sandstone, h a few flints, quartzites, igneous rocks, and hard Palæozoic ks.

The following list of derived fossils were obtained by Mr. ston from this pit:

Thecosmilia annularis (Kem), Coral Rag?
Belemnites owenii, var. *Parozianus*, Kel. Rock.
Gryphæa dilatata, „
Serpula clava (Bean), Cornbrash.
Rhynchonella varians, „
Ostrea obscura (Sow), „
Modiola imbricata (Sow), „
Pholadomya phillipsi, „
Ostrea marshi, „
Trigonia moretoni (Morris), Oolite.
  „ *costata* (Park), „
  „ *pallas* (Sow), „
Pholadomya fidicula, Inf. Oolite.
Ostrea flabeloides (Lam.), „ „
  „ *gregaria*, „ „
Lima pectiniformis, „ „
  „ *nedis* (Sow), „ „
Rhynchonella tetrahedra, Middle Lias.
Gryphæa incurva, Lower Lias.
Am. capricornus, „ „
Productus semi-reticulatus, Carb. Limestone.
Crinoid stems, „ „
Rock, with *Spirifer*, *Orthis*, and small
  univalves, Devonian. (?)
Wood, (?)

There is little evidence in the pit as to the exact position of s Plateau gravel relative to the Boulder Clay, but it extends stwards for more than a mile, and when the Waterworks mpany were laying a main in the field opposite the pit they through this gravel bed, and the evidence there obtained ws that it is Post-Glacial in date. Boulder Clay was nd filling certain large fissure cracks as well as being inter-rsed in the overlying gravel, thus indicating that some, at least, the clay reached its position before the gravel was deposited.

Returning by way of the Waterworks a swampy piece of land s pointed out through which the river Witham runs, and m some trial borings which had been made it was found that mean thickness of the swamp ground was 12 ft. of silty clay d alluvium, and underneath, and extending from side to side of the valley was found the dense blue clay of the Upper Lias. The pumping station at Saltersford happens to be on the site of a small Roman settlement, and the rough stony ford by which the Romans crossed the river at this point was found when excavating. The depth of this ford is from 9 to 10 ft. below the river level, and mingling with the stones were numerous fragments of Roman pottery and other remains. From this it is assumed that fully 10 ft. of the alluvium of the swamp has accumulated since the Romans were here.

With reference to the origin of this swamp it is significant to note that half a mile lower down the river there is an old water mill, and there being no natural fall in the river suitable for the mill, the water has had to be dammed up to get a head on the wheel. Damming the river up for this purpose would at first fill the valley, and form a long narrow lake which, by continual growth and decay of marsh plants and deposited silt, has caused a deposit of alluvium, through which the river now quietly wends its way.

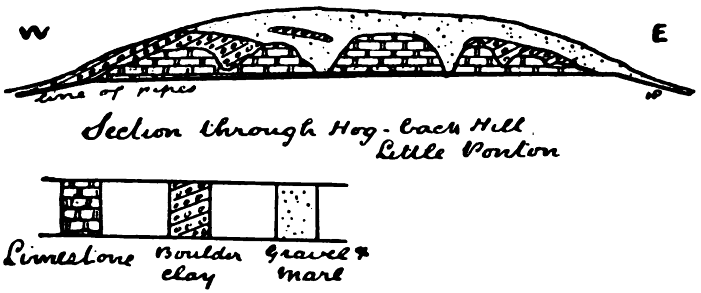

FIG. 1.

In the Papermill Lane Brickyard (Upper Lias) some very fine fluted pieces of sandstone were obtained from a pit in re-arranged Northampton Sands. These flutings are caused by carbonated water from the overlying limestone percolating amongst the sand grains, and depositing calcite as a cementing material along the runnels.

In the evening Mr. Preston gave a brief description of the geology of the neighbourhood, in the course of which he again referred to the very interesting section which was opened in the autumn of 1897 by the Waterworks Company, when they cut through the limestone hill in Little Ponton. This section, a full description of which appeared in the *Naturalist* for August, 1898, showed several large fissure cracks running parallel to the river, some of which extended below the bottom of the pipe trench (22 ft. deep), and had a width at the top upwards of 40 yards (see Fig. 1), and a measured section taken near the deepest point gave the following:

	ft.	in.
Soil	1	6
Gravel	5	0
Clay	1	6
Sand and Marl	1	3
Boulder Clay	5	0
Limestone Breccia	5	6
Hard Limestone Rock	1	9
	21	6

The study of these fissure cracks gives an interesting key to the origin of the Lincolnshire Cliff. In the geological maps of Lincolnshire (sheets 70, 83, 86), the westerly escarpment of the Lincolnshire Limestone is seen to strike almost due south from the northern extremity of the county until it reaches Grantham, where, on the south side of the town, it takes a S.W. direction. The mass of limestone which lies S.W. of the town is a great outlier, being cut off by the valley of the river Witham, and by a fault at the extreme southern edge. It is also noticed that the various streams which rise in this outlier have an eastward flow in consequence of the easterly dip of the strata, and have cut their beds to the Lias Clay. Thus the great outlier is cut up into smaller masses all resting on a clay which is inclined towards the east.

The origin of the fissure cracks at Little Ponton was explained as being due to the letting down of the rock along the western bank of the Witham soon after the river had cut through the Limestone. This had allowed the springs to wash out the sands between the Limestone and the clay, and gradual settlement had caused fracture in lines which are practically parallel with the river. These cracks have been enlarged by percolating water in the ordinary manner of swallow holes, and filled in partly by overlying material, and partly by débris of decomposed rock. Thus the tributary streams which have cut up the great outlier of Limestone into smaller masses; the underlying clay which dips eastwards towards the river; and the lateral cracks which release these masses; all combine to cause slip or creep on the lubricated and impervious Upper Lias Clay, and denudation carries away the thin edge of the Limestone without any perceptible land-slip. By degrees, then, the Limestone west of the river will be removed, and the escarpment on the east bank of the river will remain as an extension southwards of the Lincolnshire cliff.

On Friday, the 21st, the party now numbering thirty, an early start was made northwards of the town. At the Middle Gonerby Brickpits a very fine section was seen of the Middle Lias Clays immediately underlying the Marlstone Rock Bed. The floor of the pit marks the junction of the zone of *Am. Capricornus*

(Lower Lias), and the thickness of the clay face was about 60 ft., giving practically the whole thickness of these beds.

The Marlstone Rock Beds was next visited at the stone pit near the Rectory in Barkston, where numbers of the type fossils *Rhyn. tetrahedra* and *Ter. punctata* were collected. At the Honington ironstone workings typical sections of these beds were seen, showing the useful beds of ironstone which this Middle Lias Strata yields in the neighbourhood. It was here pointed out that the iron was in all probability a subsequent addition. The bed was originally deposited as an ordinary Limestone. Water containing carbonate of iron in solution had passed through it at a later date and deposited the Ferric Carbonate, many of the fossils being thus changed into carbonate of iron. At a still later period when denudation had brought the beds near the surface, so that rain-water could act upon them, the iron carbonate was altered into the more useful iron oxide.

Walking by way of the Honington Camp—a well-defined rectangular structure, probably of Roman date—a visit was paid to the Ancaster Quarries. These quarries are for working the Freestone of the Lincolnshire Oolite, and some remarkably good sections were seen of the limestone overlaid by the Upper Estuarine Clays. One section of these beds gave the following:

		ft.	in.
Soil and Rubble		1	6
Grey Clay, iron-stained		1	6
Band of hard, dark-coloured Marl			1
Grey, stony Shale, with *pinnæ* and *oysters*		1	5
Green Clay		5	0
Dark blue and purple laminated Clays		15	0
Lincolnshire Limestone	Coarse red ragstone		6
	Freestone	10	0
	Rough bed rock, seen to	4	0
		39	0

The Lincolnshire Limestone has been shown to belong to the Inferior Oolite Age. In the *Geol. Mem.* for Sheet 64, Prof. Judd gave a series of sections starting from Bath and taken across the country in a N.E. direction to the Yorkshire coast, and the diagrammic section, shown by the Director, was based upon these sections. Starting with a typical development of the Lower Oolites in Gloucestershire, the diagram showed how most of these beds thin out or alter their facies when traced northwards, until in the north east of Yorkshire the Lower Oolites become quite different in character and organic remains to what they are in the S.W. The two most constant beds are the Cornbrash and the Upper Zone of the Great Oolite Limestone. The Cornbrash is remarkably uniform in both character and thickness right acros the country, and a portion of the Great Oolite Limestone (Bath Oolite) is almost equally constant.

In the Cotswold Hills the Great Oolite Limestone is divisible into an Upper and Lower Series. The Upper Series continue fairly uniform in character right across the country into North Lincolnshire, whilst the Lower Series very soon begin to put on an Estuarine appearance, first developing the Stonesfields Slates at their base, and, finally, at Northampton, become changed into a true Estuarine Bed, and known as the Upper Estuarine Series.

FIG. 2—FOLD WITH FISSURE CRACKS IN LINCOLNSHIRE LIMESTONE, WILSFORD, NEAR ANCASTER.

(Block kindly lent by "The Naturalist.")

Thus the Upper Estuarine Clays of Northamptonshire and Lincolnshire are the equivalent of the Lower Series of the Great Oolite Limestone of the Cotswold district. The Lower Division, also of the Inferior Oolites, when traced across the country in the same direction, are soon found to be developing Estuarine characters, first changing into the Pea Grit, and then putting on more and more of a sandy character until they become known as ie Northampton Sands, the Upper Beds of the Inferior Oolite aving died out.

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In North Northamptonshire these two Estuarine Series are found in contact, *i.e.*, the Sandy representatives of the Lower Series of the Great Oolite (Upper Estuarines), and the Sandy Series of the Lower Beds of Inferior Oolite (Northampton Sands) are in juxtaposition, but retain distinct characters.

Just before leaving Northamptonshire a thin wedge of limestone comes in between these Estuarine Beds which quickly develops into a thick Series of Limestones traversing the whole of Lincolnshire, and known as the Lincolnshire Limestone. This mass of Limestone is 132 ft. thick at Boothby Pagnall, south-east of Grantham, but thins out again away northwards, dying out altogether just as it reaches Yorkshire, or becoming lost in the thick series of Estuarine Beds. Thus the stratigraphical position of the Lincolnshire Limestone, as well as its petrological and palæontological characters, all point to its being of Inferior Oolite age.

The section of limestone in the railway cutting at Wilsford was next visited, where there is an interesting anticlinal fold about half a mile long, and in which are several large fissure cracks (Fig. 2). These fissures, which are from 30 to 40 ft. wide, extend across the railway cutting in a N.E.-S.W. direction, and the strike of the fold is in the same direction. Several large masses of Upper Estuarine clay were examined, which had been let down into the fissure during their development, thus pointing to the period in their history when these clays rested on the limestones at this point, but which have since been denuded.

Passing thence through the ancient valley at Ancaster and Honington, occasion was taken to refer to the origin of this and the Lincoln gap. Amongst the very interesting features in connection with the Lincolnshire Cliff are the two gaps which have been cut through it by rivers which have since abandoned their old courses and taken fresh ones. The Lincoln gap was cut by the river Trent before it was captured by a longitudinal stream or valley and carried along its present course to the Humber. The Honington gap was cut by the river Witham, flowing thence in a more direct line to the Wash. At some comparatively recent geological period the foldings of the strata at Wilsford seem to have diverted the course of this ancient stream, throwing it out of its old valley and causing it to take a northerly direction past the Honington gap, through the Lincoln gap, and thence along the ancient course of the Trent, to Boston and the Wash. So completely have the folds altered the contour that they form the watershed of two small streams which run in opposite directions, one flowing westwards as a tributary of the Witham, whilst the other flows eastwards and becomes the river Slea.

Saturday, the 22nd, was devoted to a study of the Liassic strata and the Northampton Sands Ironstone at Lincoln.

A visit was first made to the Upper Lias pit on Burton Road (Lincoln Brick Co.) which was formerly noted for Upper Lias

very beautiful. The villa was first discovered in 1884, illustrated and described in the Reports and Papers of the Architectural Societies of Lincoln and Nottingham for the year 1891, and mentioned in the *Archæological Journal*, vol. xii.

Time did not permit a visit to the new boring at the Waterworks, but Mr. Teague, the engineer, had kindly sent for distribution a quantity of specimens of a beautiful light greyish blue anhydrite which had been obtained from the Keuper Marls at depths of 709 ft. and 730 ft., the bands being 1 ft. 3 in. and 1 ft. 10 in. respectively.

The following analysis of the stone was made by P. E. Spielmann, A.R.C.Sc., A.I.C., who says: "The substance is of a blue colour of varying depth, with occasional pink and brown patches, and is of an indeterminate microcrystalline character.

"Considering the theoretical amount of water required for the calcium sulphate to be present as gypsum is 20.10 per cent., the deposit is mainly a bed of anhydrite, which is becoming hydrated, such as is found, for instance, at Bex, in Switzerland. Deposits of mixed anhydrite and gypsum are known in the Carboniferous formation in Nova Scotia, and at Oulse, in Italy.

"The blue colour, which is destroyed on prolonged heating and is not regained on moistening, is an intrinsic property of the mineral, and is not due to the effect of the strontium sulphate in the form of celestine, nor to iron in the low state of oxidation. Anhydrite is found blue at Berchtesgaden, Bavaria, Lockport, U.S.A., and in other localities.

"The presence of strontium sulphate with anhydrite has been noticed in other deposits. The iron is probably present as ferric sulphate in the pink and brown patches and veins. In the above analysis the amount of K_2SO_4 was calculated from the amount of SO_4 unaccounted for by the other sulphates, and the sodium chloride by difference; the radicals were so assigned on account of their relative solubilities."

$CaSO_4$	75·98
$SrSO_4$	3·92
$MgSO_4$	0 63
$Fe_2(SO_4)_3$	1·01
K_2SO_4	2·16
NaCl	0·13
H_2O	15·17
	100·00

The deep well at Boultham for the Lincoln water supply, has up to date reached a depth of 900 ft., as follows:

	ft.	in.
Soil and Drift	22	0
Lower Lias	618	0
Rhætics	59	0
Keuper	201	0
	900	0

FIG. 1.–CHARLES STREET CLAY PIT, LOUTH.

FIG. 2.—HUBBARD'S VALLEY, LOUTH.
Photos by Godfrey Bingley.

Details of the section are given in the *Geol. Mem.*: Water Supply of Lincolnshire, under the heading Boultham.

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SATURDAY, APRIL 22ND.

[*Reports by* Prof. KENDALL and the Rev. LOWER CARTER, M.A. (Tuesday).]

On the arrival of the party at Louth it was met by the Directors, Rev. W. L. Carter and Professor P. F. Kendall, who were accompanied by members of the Yorkshire Geological and Polytechnic Society, the Hull Geological Society, and the Louth Natural History Society. The more energetic spirits proceeded at once to a brickyard at Charles Street, Louth, where a splendid section of boulder clay was examined.* The major part of the face consisted of dense lead-coloured clay with abundant well-scratched stones, but near the top an irregular bed of gravel separated off a bed of boulder clay of a russet colour. The lower bed seems to agree with the Purple Clay of Searles Wood, and the upper one may perhaps represent the Hessle Clay. It was hoped that decisive evidence might be obtained from the examination of the boulders present, as in Yorkshire the Hessle Clay appears to be everywhere characterised by the abundance of porphyrites of the Cheviot type in association with greywacke sandstones such as occur in the Tweed Valley, and these rocks were found not only among the loose boulders, but also in the clay itself.

Many interesting erratics were observed, including examples of Scandinavian rocks such as in Augite Syenite (Larvikite) from the country near Christiania.

MONDAY, APRIL 24TH.

The party proceeded by train to Withcall, a station on the

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* *Cf.* Fig. 1, Plate III.

ere it was observed that beds of hard and sound sandstone assed quite abruptly into loose sand. Some of the harder locks yielded a few fossils, chiefly small Pectens, with occasional asts of Belemnites. From the viaduct over the River Bain an nteresting study could have been made of the complex windings f the river and the numerous abandoned meanders, and the ontrast between the swampy condition of the Kimeridge utcrop in the floor of the Bain valley, and the dry hills of the pilsby Sandstone were marked features of the landscape.

The next series of cuttings displayed the Spilsby Sandstone nder many aspects, in one place so strongly ferruginous as to uggest a possible economic value as an ironstone; in another, oft white sand, and in yet a third, a hard, dark-green glauconi-erous sandstone, with many pebbles of Lydianite, and some ossils. The special feature of these cuttings was the fine evelopment of the Claxby Ironstone, and the beauty and variety f the fossils contained.

The rock consists mainly of oolitic grains, sometimes quite oose, and in the condition of sand, at other places, or on other orizons, the grains are held in a matrix of marly texture. The rains are stated by Professor Judd to be largely chalcedonic, but here is also much limonite in their constitution. The process hereby the original carbonate of lime gave first its lime in xchange for an equivalent of iron, and then parted with the arbonic acid and became a hydrous oxide of iron is a amiliar and interesting one, but there is much to learn about it, nd there is a further subject for investigation in the presence of he chalcedony. Whence was the silica derived? Was it of rganic origin, or did it come from the decomposition of lauconite? These are questions that may well be considered y future visitors to the Donington sections.

Palæontologists found plenty of material in the Ironstone—e fatigue-party of plate-layers plied pick and shovel on their ehalf with a disregard of consequences to the "batter" of the uttings, surprising to those who know how precious to the ilway-engineer is the preservation of a sound and proper slope. he principal fossil bed is near the contact of the Claxby Iron-one with the underlying Spilsby Sandstone, and every stroke f the pick brought out fine examples of the Trigonia, Lima, ucullæa and Astarte, with more rarely Pectens, Brachiopods, nd Belemnites, including the zone fossil *B. lateralis*. Glimpses ere obtained of the mighty *Pecten cinctus*, but no perfect pecimens were secured.

It was with great reluctance and symptoms of mutiny that e keener collectors obeyed the presidential whistle and took p the line of march again, leaving the cuttings strewn with ébris, from which the next comers will probably glean a richer arvest than was gathered by the reapers themselves.

At Benniworth tunnel the party divided, some going through the tunnel attended by acolytes bearing naphtha flares, while others mounted over the top to get the fine prospect afforded of the Neocomian and Chalk escarpment to the eastward and the great plain of the Jurassic clays to the westward.

The village of Benniworth was visited for the purpose of examining a famous erratic, "the Bluestone," an igneous rock whose place of derivation will, as the outcome of this visit, be made the subject of a careful inquiry.

The route now led past a fine exposure of boulder-clay, composed, so far as matrix and contents were concerned, chiefly of Kimeridge Clay with its septaria, and Spilsby Sandstone. Flints and fragments of chalk were present, and a few rocks derived from beyond the confines of Lincolnshire.

A large abandoned brickyard near South Willingham Station gave abundant evidence of Kimeridge Clay, with its septaria and characteristic Ammonites. The day's walk had given exposures of the full succession from the Lower Chalk, through Red Chalk, Carstone (Tealby Limestone), Tealby Clay, Claxby Ironstone, and Spilsby Sandstone, to the Kimeridge Clay, except only that Tealby Limestone, which is mapped by the Geological Survey as present, was not encountered.

At South Willingham the programme was completed, but the railwaymen told of great boulders in the sides of a cutting half a mile farther, so away went the energetic members, and theirs was the find of the day.

The boulders proved to be immense blocks of grey sandstone, containing great numbers of fossils, chiefly Ammonites and Astartes, with a few gasteropods. Desperate attempts were made to hew off lumps containing these treasures, and a partial success was achieved, but the bag, though heavy, was not absolutely satiating, for not only were the fossils in beautiful condition, but the rock was a new type. No critical examination of the fossils has yet been made, but it is quite clear that the boulders represent a phase of the Spilsby Sandstone far richer in fossils, both in respect of numbers and variety, than any as yet known *in situ*. Abundant material still remains to satisfy future collectors for a long time.

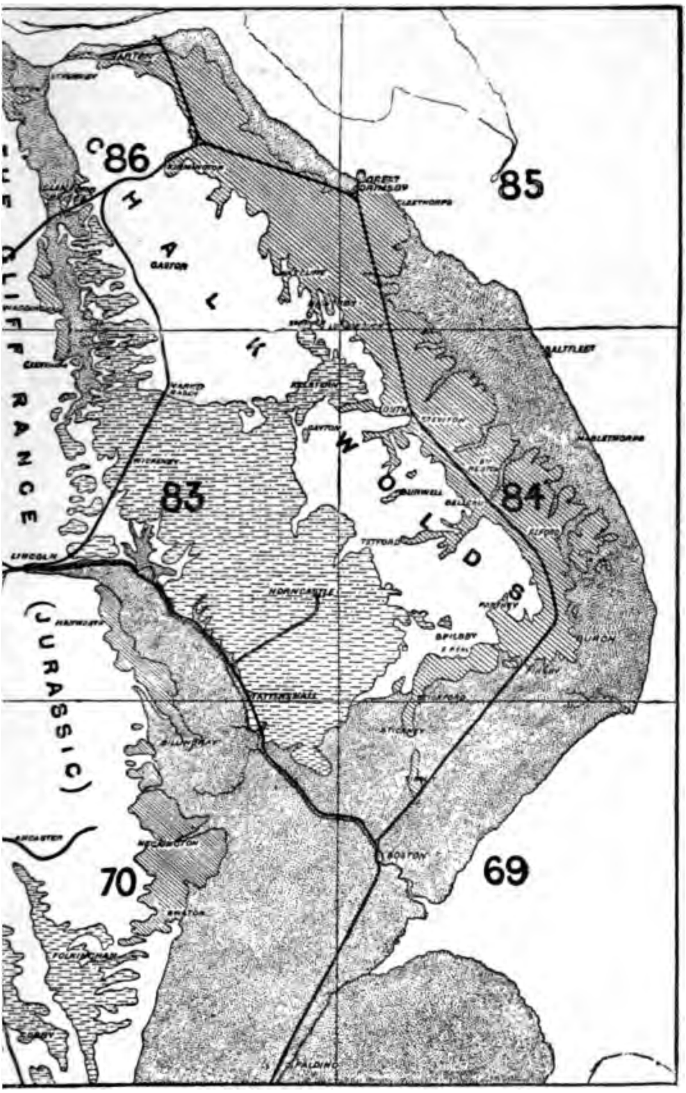
In the evening, at the Mechanics' Institute, the members of the Louth Natural History Society provided an interesting series of local specimens, and the Rev. W. L. Carter expounded his views on the formation of some of the Lincolnshire valleys.

TUESDAY, APRIL 25TH.

This was devoted to an examination of some of the glacial features of the Lincolnshire Wolds, which are being studied by the Directors of the excursion. The party drove by waggonette

MAP OF LINCOLNSHIRE, SHOWING THE RANGE OF THE
ER CLAYS, REDUCED FROM THE MAPS OF THE GEOLOGICAL SURVEY.—*A. J. Jukes-Browne.*

(Scale about 12 miles to an inch.)



tted ground = Marsh and Fen. Dash and dot = Chalky Clay.
Diagonal lines = Hessle Clay.

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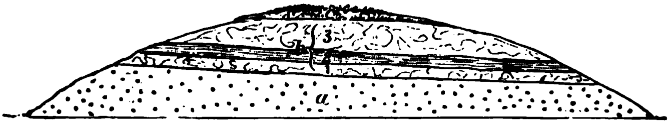
SKETCH OF BENNIWORTH-HAVEN CUTTING.

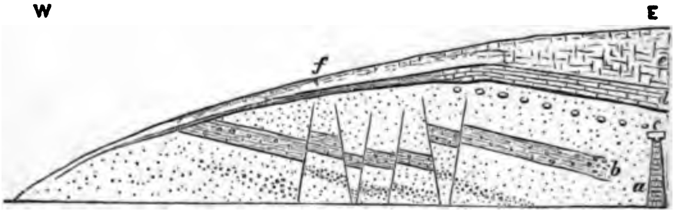


a. Lower Sands. *b.* Ironstone. *c.* Soil with flints from the drift.

DIAGRAM OF RAILWAY-CUTTING E. OF S. WILLINGHAM STATION.

a. Kimmeridge Clay. *b.* Line of Septaria. *c.* Line of Phosphatic nodules in *d.* Lower Sands. *e.* Surface soil.

SKETCH OF CUTTING AT WEST END OF WITHCALL TUNNEL.



a. Brownish and reddish-brown sands. *b.* Band of phosphatic nodules.
c. Line of ferruginous concretions.
d. Red chalk, 9 ft.
e. Greyish-white chalk, 8 to 15 ft. above the tunnel.
f. Re-arranged red and white chalk.

DIAGRAM OF CLAXBY RIDGE.

a. Lower Grits and Sands. *b.* Ironstone. *c.* Grey clay with nodules. *d.* Tealby Limestone. *e.* Upper Sands,

All by H. Keeping.

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THE CORRELATION OF THE SPEETON SERIES IN YORKSHIRE AND LINCOLNSHIRE.—*G. W. Lamplugh.*

Fossil Zones.	*Western edge of Yorkshire Wolds.*	Knapton, Yorkshire.	Speeton Cliff.	Nettleton Hill, Lincolnshire.	Southern part of Lincolnshire Wolds.
	Red Chalk	Red Chalk.	Red Chalk.	Red Chalk.	Red Chalk.
A. Zone of *Bel. minimus*, List.	Ferruginous sands and pebble-beds.	Marls with *Bel. minimus*	Marls with *Bel. minimus.*	Carstone.	Carstone.
B. Zone of *Bel. brunsvicensis*, Stromb.	Wanting.	Clays with *Amm. deshayesii.*	Blue Clays with Calcareous nodules.	Tealby Limestone.	? Upper Clay and Reach Ironstone.
C. Zone of *Bel. jaculum*, Phill.	Wanting.	?	Striped Clays with nodular ferruginous bands.	Tealby Clay.	Tealby Clay.
D. Zone of *Bel. lateralis*, Phill.	Wanting.	Wanting ?	Pyritous Clays with nodular bands.	Claxby Ironstone.	Tealby Clay of Hundleby and Hundleby Ironstone.
				Spilsby Sandstone.	Spilsby Sandstone.
E.	Wanting.	Wanting ?	Coprolite Bed.	Phosphatic Nodule Bed.	Phosphatic Nodule Bed.
F. Shales with *Bel. owenii*, etc.	(Usually) Wanting.	Kimmeridge Clay.	Kimmeridge Clay.	Kimmeridge Clay.	Kimmeridge Clay.

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to Raithby and Tathwell. A halt was made on the top Stanmore Hill to view Hubbard's Valley,* a glacial chan which now carries the drainage of the Tathwell and With Valleys, and an examination of sand and gravel was made i pit near Tathwell. The field-road was then taken to Bully H where a glacier-lake overflow, cutting through the 300 ft. cont was examined. This is the easternmost of three parallel overfl channels cutting through a Chalk spur at intervals of about a m and, in the opinion of the Directors, marking three stages in t retreat of the ice-sheet. The party viewed the central channel Orgarth Hill Farm, which is choked at the watershed by bould clay. A chalk pit showed a tongue of boulder clay thrust und the disturbed chalk. For some time the eastern side of th valley at the watershed appears to have been formed by the ic front.

The Orgarth Hill valley was followed southwards, where deepens into a fine gorge in solid Chalk, and the valley of norm (spring) drainage which runs at right angles to the overflo channels was crossed. The party then traversed some of t continuation glacier-lake channels to the south. These for three sets of winding dry gorges, each one of which has be found to agree with one of the three channels through t Bully-Orgarth ridge. Foreign drift pebbles and boulders we found in the ploughed fields in abundance, and the movemen of the ice-sheet, which it is presumed caused these channel were explained by the Directors. After partaking of tea Walmsgate, the channel through Great Covert was followed Swaby, where a great moraine was shown to obstruct the vall and to have diverted the stream by a sharp cut through t Chalk to the east. The question of the formation of the valleys by springs was considered, but the Directors point out that the valleys considered by them to be glacial-overflo ran directly through the watersheds of spurs separating valle of normal spring-drainage, and, in their opinion, could not explained otherwise than by glacial action, and that the evide from the whole of the west face of the Wolds formed a str chain of connected facts supporting this contention.

In the evening members were invited to the King's H where the Yorkshire Geological and Polytechnic Society h their general meeting, and some interesting papers were r followed by keen discussion.

WEDNESDAY, APRIL 26TH.

The last day's work was in many respects the best. The p drove out from Louth by way of Ludford to the crest of the g

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* *Cf.* Fig. 2, Plate III.

Cretaceous escarpment above North Willingham, and traversed on foot the whole sequence from the Lower Chalk to the Kimeridge Clay. There are minor escarpments forming steps in the main one, and so it is easy to trace each division whether exposed or not: thus the "tread" of the top step is formed by the Red Chalk exposed in several shallow pits, and traceable also by the red band running along the hills, the "rise" is composed partly of Red Chalk and partly of the soft underlying Carstone. Next comes the Tealby Limestone forming the next tread, with the underlying Tealby Clay and Ironstone; Spilsby Sandstone makes a narrower step, but its outcrop is boldly marked by a sandy belt with gorse and Scots pine and occasional protrusions of bare rock, then the Kimeridge Clay slopes away into the plain.

Some time was spent in the examination of the Tealby Limestone, here seen for the first time by the party. It is exposed in a couple of quarries from which some very convincing examples of *Exogyra sinuata* and *Pecten cinctus* were obtained, one specimen of the latter in shape and size bearing a not remote resemblance to "Mambrinus's helmet." Mr. Stather, of Hull, was fortunate in obtaining from a rockery in the village of North Willingham two very fine Ammonites which had been obtained from one of the quarries.

A large sandpit has been dug in the Spilsby Sandstone, which here shows its usual character of abrupt transitions from loose sand o rock. One remarkable instance was observed in which a hard cylindrical column of sandstone displayed a concentric structure which gave it a resemblance to a gigantic tree-trunk.

At the foot of the escarpment the carriages were remounted, nd a drive of three or four miles through a sandy country with pine-woods and warrens brought us to the famous brickyards near Market Rasen. A good section is visible, displaying the ower division of the Kimeridge Clay overlain by blown sand the same that encourages the pine-woods and gives to all the country round Market Rasen an aspect of dryness in apparent contradiction of the Kimeridge Clay which makes so large a figure in the "Solid" maps of the district). A short stay was made at the brickyards and the workmen's store of fossils, bought in bulk by the Directors, and afterwards distributed by lot amongst the members, some of whom were won over by the exquisite beauty of the specimens to an unwonted enthusiasm for collecting. Many small and a few large examples were obtained of the gorgeous iridescent Ammonites for which the place is famed, besides which some hundreds of lesser treasures, such as *Trigonias*, *Nuculas*, etc., were distributed.

The party now proceeded by a circuitous route—the only one available for vehicles—to Claxby, a pretty village at the foot of the escarpment, and thence walked to the once famous ironstone mines at Acre House, where the Claxby Ironstone was worked some thirty years ago. The underground workings are not in a fit state for exploration, but the slopes of the great spoil-heaps furnished opportunities for observation of the character of the ironstone and for fossil collecting. Very good specimens of Brachiopods and of *Belemnites* (*B. lateralis* and others) were found, but the masses of ironstone crowded with great attractive-looking specimens of *Pecten cinctus* were very tantalising, as the *Pectens* were all severely cracked, and it was practically impossible to extract a whole specimen.

The junction of Neocomian series with the Kimeridge Clay was fairly well seen in the excavations at this place, and the shales of the latter formation contained the usual crushed Ammonites of the biplex type. The walk from the mines down to Holton station afforded an opportunity of observing the wide extent of country covered by blown sand, and a brickyard near the railway gave another exposure of the lower part of the Kimeridge Clay nearly on the same horizon as the Market Rasen pits. The famous fossil bed is occasionally reached in the deeper excavations, and a few specimens rewarded the collectors.

From Holton station the members dispersed in various directions, and the excursion was at an end.

It should be mentioned that some members of the Association took advantage of an opportunity which presented to examine some of the chalk pits to the north of Louth. They visited a pit at Boswell,* in which Mr. W. Hill, of the Geological Survey, recognised the occurrence of Upper Chalk fossils, which had not been observed in Lincolnshire at the time when the area was surveyed. Several characteristic fossils were obtained, including *Holaster planus*, *Micrasters*, and *Ananchytes*. Another pit near Fotherby was visited, and although no absolutely diagnostic fossils were found, the occurrence of gigantic *Inocerami* raised a strong presumption that the Upper Chalk was represented. In this pit persistent, almost continuous, bands of tabular flints of gigantic size were present.

Our thanks are due to the Council of the Geological Society of London for the loan of blocks, and to the Editor of "The Naturalist" for the loan of blocks for photos.

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* *Cf.* Fig. 2, Plate V.

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EXCURSION TO WOLDINGHAM.

SATURDAY, MAY 6TH, 1905.

Director: W. WHITAKER, B.A., F.R.S., F.G.S.

(*Report by* N. F. ROBARTS, F.G.S.)

THE excursion, which it was arranged should be conducted by Mr. W. Whitaker, in order to visit some outliers of Lower Eocene Beds upon the North Downs, was unfortunately deprived of his guidance, over ground the geology of which he has made his own, owing to the severe illness of a member of his family. Mr. Whitaker was, however, able to meet the members as they passed through the station at South Croydon, and let them know that he had arranged with Mr. N. F. Robarts, F.G.S., to guide them over the route he had intended to take them. On arriving at Woldingham, the party was found to number thirty, including three or four members of the Croydon Natural History and Scientific Society, whom Mr. Whitaker had invited to join the excursion.

The Director first led the party almost as far as Bughill Farm, the point at which the members of the Association had seen the source of the flow of the Croydon Bourne at the excursion of March 12th, 1904, where he took the opportunity of saying a few words upon the origin of the Bourne flow for the benefit of those members who had not been present at the previous excursion. Retracing their footsteps a short distance, the Director led the party up a dry chalk valley, the north side of which they ascended, gaining a height of about 700 ft., from whence was obtained a good view of the chalk tableland of the Surrey part of the North

Downs, intersected with numerous dry valleys. Descending i another dry chalk valley, noticing on the way numerous neoli flakes, amongst which were found one or two rude scrapers, party ascended the north side of this second valley to a small c pit which appeared almost unfossiliferous, although fragment Inoceramus were noted. The chalk was much disturbed jointed, whilst some nodular blocks were noticed lying in the but could not be traced *in situ*. The zone was therefore ind minable, although probably in Lower Chalk. A heavy was Tertiary pebbles from the hill above covered the upper part of pit. Still further ascending Nore Hill, the party reached gravel pits in Blackheath pebble beds, which latter appeare overlie and partly to fall into pipes in the chalk, containing sa of Oldhaven or Woolwich and Reading beds, in one p hardened into a soft sandstone, together with a few greenish angular flints at the sides of the pipes, which were proba derived from the remains of the base of formerly existing Tha Sand, but no other traces of this bed were apparent. The sa and pebbles appeared entirely unfossiliferous, but the latter w in some places hardened into conglomerate by oxide of i which gave the beds a strong pinkish-red colour. Mes Robarts and H. W. Monckton made a few remarks upon section, the former pointing out the small size of the pebb The walk was then continued through Slines Oaks to the w known section in Blackheath pebbles at Worms Heath. H very similar features were observed, but the bed was thicker, section showing a face of some 60 ft. in depth, whilst the peb were larger, and the ferruginous conglomerate lay in very h and large masses.

There happened to be no chalk visible, all the sides of pipes or pillars having been cut away, but pockets of sand sandstone were seen with green-coated flints, showing probably these sands were the contents of pipes in the ch indeed, as pointed out by the Director, it was possible that whole pit was part of a very large pipe.

The Director again called the attention of the party to details of this, the principal outlier of Blackheath pebbles on crest of the Downs, and to the occurrence of allophane (a hydr silicate of alumina) in parts of the pit, and to a small bed subangular flints overlying the pebbles in the highest part of pit. The party then crossed on to the mounds on Worms He marked as Ancient Camp on the Ordnance Map, about wh the Director made a few remarks, pointing out that they w probably only old gravel workings, and at the same time g some information respecting a prehistoric camp lying a littl the north.

This concluding the geological work of the afternoon, Mr. W. Monckton, Vice-President, proposed a hearty vote of tha to the Director, which, having been duly acknowledged by Mr. Robarts, the members walked about three miles, passing a large chalk pit in the Lower Chalk, to the coffee-house at Upper Warlingham Station, where they partook of a substantial tea, and returned to London by the 6.58 p.m. train.

EXCURSION TO READING AND CAVERSHAM.

SATURDAY, MAY 13TH, 1905.

Directors: H. W. MONCKTON, V.P.L.S., F.G.S. AND
O. A. SHRUBSOLE, F.G.S.

Excursion Secretary: H. KIDNER, F.G.S.

(*Report by* THE DIRECTORS.)

ARTING from Reading Station at about half-past two in the ernoon a party of twenty-three crossed the Thames into xfordshire at Caversham.

After passing through the village, Mr. Shrubsole drew atten- n to a section in the bank at the side of the Peppard Road. showed gravel resting on Chalk at a level of 168 ft. O.D. He id that the gravel belongs to a terrace which has yielded flint plements and also remains of the Mammoth. The gravel is loured Plateau Gravel on the new edition of the Geological rvey Map. It is however, within the valley. Mr. Monckton marked that owing to the way in which the sheets of gravel tended from the plateaux into the valleys in the district it had en found convenient to colour as Plateau Gravel several tches and terraces which, though in the valley, were above the ttom of the valley, and seemed more closely connected with e gravel on the hill top than with that at the bottom of the lley. He mentioned the Grovelands terrace as a good example.

Near the top of the hill the party passed on to the Emmer reen Outlier of Eocene Beds. This outlier is to a large extent vered by gravel, and a pit was visited at a level of 269 ft. O.D. he gravel seemed to be about 10 ft. thick, was roughly stratified, nd of a reddish colour. A few pebbles like those of the Triassic ebble Beds were noticed, but they did not seem common.

Mr. Shrubsole said that occasionally implements had been ound at this place.

Leaving the pit the party halted at a point from which a fine iew of the valley of the Thames and the surrounding hills was btained, and Mr. Monckton made some remarks on the geological story of the district. He said that the oldest formation at the rface of the ground before them was the Chalk, a bed of marine origin, and it was succeeded with sundry breaks such as the period of the Mottled Clay by other strata of marine origin until the deposition of the Upper Bagshot Beds which formed Easthampstead Plain and some of the high ground seen in the distance. The Upper Bagshot is of the age of the Lower Barton Beds of Hampshire, and they are the last sign of the sea in this district, for there is no evidence that the Lenham-Bed Sea extended on the Reading side of Guildford.

At some time since Lower Barton days the area has become land, and also great earth movements have taken place, forming the folds which have given rise to the Thames Basin.

The speaker said that up to the present it had not been determined how much of the folding had taken place since the country became land, but however that might be the composition of the various gravels had led him to believe that the gravel on which they were standing had been brought down by the Thames, that the gravel-sheets of Bucklebury Common, etc., were formed by the Kennet and those of Easthampstead Plain, etc., by the Blackwater. At the same time he thought he ought to state that this view had not been fully accepted by geologists.

The party then walked to the brickfield at Rose Hill. The clay worked belongs mainly to the Reading Beds, but in one part of the pit the Directors pointed to *septaria*, and shells evidently from the London Clay and its basement bed, and in one place there appeared to be some London Clay in the side of the section.

The explanation is shown on the Geological Map, a patch of London Clay having been let down to the level of the Reading Beds by three faults arranged in the form of a triangle. It is probable that the place, where what appeared to be London Clay was seen in the section, was on the line of the northernmost of these faults.

Overlying the clay there is a patch of gravel with a level of 305 ft. O.D. Pebbles from the Triassic Pebble-Beds are abundant, and Mr. Shrubsole mentioned that he had found fragments of igneous rock. He remarked on the large amount of loam in the gravel, and thought that it indicated a broad rather than a rapid stream, with probably a lake-like condition, at times. He knew of no implements from this gravel. The party then crossed the dry chalk valley to the west of the Emmer Green outlier, and visited a gravel pit in the Kidmore Road, 265 ft. O.D. The gravel is fairly well stratified, of a dark colour, and contains many pebbles like those of the Triassic Pebble Beds. A few worked flints were found by members of the party.

This pit is in the same sheet of gravel as the former working at Toot's Farm, from which many fine implements have been obtained, but the site of that working and indeed most of the implementiferous drift of this patch is now built over.

The large chalk pit at Caversham, which was visited in 1876 ("Record of Excursions," p. 272), was passed on the way back to Reading.

Tea was served at McIlroy's Restaurant, and after a hearty vote of thanks had been given to the Directors, the members visited the Reading Museum, where the collection of flint-implements attracted special attention. The Museum was kept open specially for the members through the kindness of the curator.

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EXCURSION TO ERITH AND CRAYFORD.

SATURDAY, MAY 20TH, 1905.

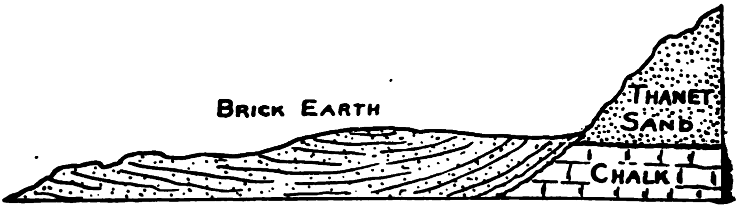
Director: A. L. LEACH.

Excursion Secretary: H. KIDNER, F.G.S.

(*Report by* THE DIRECTOR.)

A PARTY of twenty-six met at Erith station at 2.47 p.m., and walked along the main road towards Crayford. To the west of this road the brickearths were seen to be excavated back to the buried cliff (of chalk and Thanet sand), which forms the western boundary of the River Drift in the Darent Valley. About a mile south of Erith the party entered "Norris's Pit" at North End. Here an interesting section (Fig. 1) of the Chalk, Thanet Sand, and brickearth was examined. The Chalk was seen to pass into the hill to the west without appreciable dip. The "Bullhead" bed, or base of the Thanet sand, was seen to be well developed, and reference was made to the theory by which Mr. Whitaker and Professor McKenny Hughes explain the origin of this bed. It was, however, pointed out that both here and at Charlton many flints occur of ovoid and well-rounded forms, and their presence is not explained by the theory of the underground solution of the chalk by percolating carbonated water. The Thanet Sand, about 25 ft. thick, was briefly glanced at, and then the disposition and materials of the Pleistocene River Drift were examined. In the Crayford district this Drift consists largely of brickearth associated with sandy and pebbly layers, very variable in lateral extent and in thickness. On the west the Drift is banked against and bounded by a buried cliff of chalk and lower tertiaries; on the east the Drift passes beneath the recent alluvium of the Thames and Darent. Using the term "brickearths" to include not only the commercial brickearth, but also the sandy and pebbly layers associated with the sandy clays the brickearths may be said to lie between the "High Terrace" Gravels of Dartford Heath and the "Low Terrace" Thames Gravels; these latter are covered by the alluvium.

In "Norris's" pit the sloping chalk cliff was seen to be faced with a hard chalk conglomerate. Insomuch as this formed the river bank at the time of the deposition of the brickearths, it may be considered a "Palæolithic floor," comparable with the floors found in many other districts. The brickearths resting against the chalk bank are shelly sands containing abundant fragments of *Tertiary* shells. The Director showed specimens of *Melania*, *Cerithium*, and *Cyrena* obtained in this section; these indicated the denuded Woolwich and Blackheath beds of the district as the source of the materials of the lower brickearths. In the same section the upper brickearths were seen to be thinly bedded and much more clayey than the lower beds. The abundant mammal remains of the Crayford district have been found chiefly in the lower sandy beds.



No. 1.—SECTION NEARLY EAST AND WEST AT NORTH END PIT, NEAR CRAYFORD.—*A. L. Leach.*

Length of Section, 50 yards. Vertical Scale 2½ times horizontal.

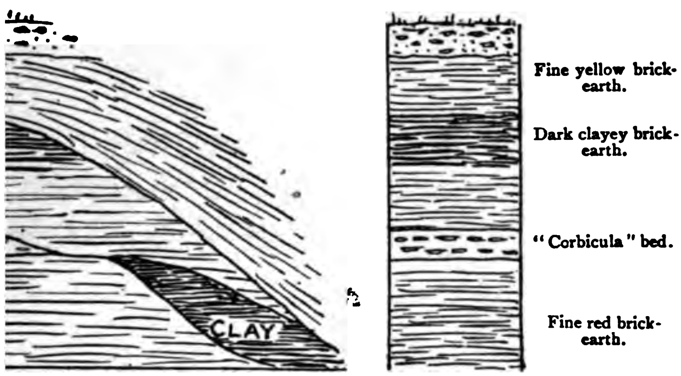
Leaving this section the party proceeded to examine some large blocks of shelly conglomerate lying on the slopes of the brickearths. The Director showed specimens of *Fusus* (2 sp.), *Aporrhais*, *Calyptræa*, *Natica*, *Cyprina*, *Panopæa*, *Pectunculus* (2 sp.), extracted from these blocks. This assemblage of fossils indicates the basement bed of the London Clay as the probable source of the shelly conglomerates. Probably the blocks have not drifted far; conglomerates containing similar fossils were dug up in Bexley Heath during 1904. In this district traces of the basement bed possibly remain *in situ*.

Section 2 in "Norris's" pit was next visited. Here the pit has been excavated to the level of the lower sandy beds. Above these lie at least 30 feet of thinly bedded clayey brickearth in which numerous remains of elephant, rhinoceros, etc., have been found. About six feet above the floor of this pit a thin sandy

:curs, which varies from six inches to a foot in thickness, and ns *Corbicula fluminalis*, *Bythinia*, *Planorbis*, etc. *Unio lis* and *Anodonta* also occur either in the shelly band or in djacent clayey layers. This "Corbicula bed" has been over a large part of the brickearth area, but the shells ıt always abundant.

ıe southern face of this cutting (Fig 2*a*) showed the brick- dipping sharply to the west. No explanation was offered s curious departure from the usual type of bedding. Some d flakes obtained in this pit were inspected. The party ɔroceeded to " Rutter's " pit, where the cutting *west* of the road was first examined.

ere the section (Fig. 4) is similar in most respects to


ight angles to No. 2). No. 2.

·IONS IN THE NORTH END PIT, NEAR CRAYFORD.—*A. L. Leach.*

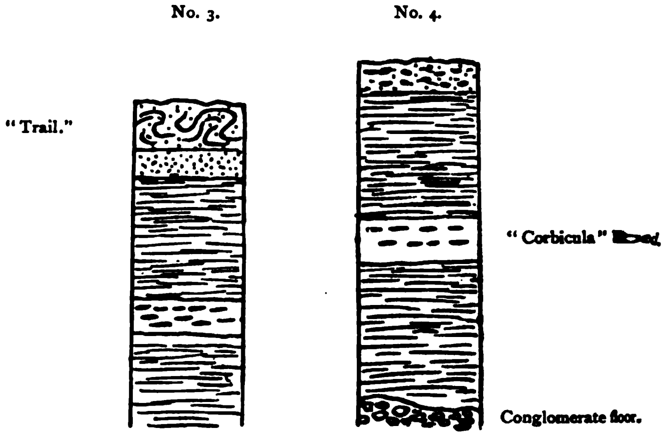
ın 2 in "Norris's" pit, but the thickness of brickearth ater, and the floor of the pit is formed by a curious pebbly ɔmerate, consisting chiefly of rolled and unrolled flints ıted by calcareous "race." Many pebbles of crystalline ;, sandstone, and quartzite also occur. (*N.B.*—This con- rate floor is only shown in a new pit lying west of the road, ɔnnected with " Rutter's " large pit by a tunnel. This pit was d in 1904.) Many bones of the large Pleistocene mammals ›und here. The " Corbicula bed " is clearly marked, but are somewhat scarce.

eturning through the tunnel into the larger and older pit, the n along the north side was examined. Just below the main ı very fossiliferous pocket was pointed out in the " Corbicula

While some members of the party collected fossils others :ted some typical specimens exhibited by Mr. R. H.

Chandler. Amongst them were *Corbicula*, *Bythinia*, *Pisidium*, *Planorbis* (2 sp.), *Helix*, *Valvata*, *Unio*, and *Anodonta*.

Towards the east of the section (*i.e.*, in the direction of the Darent) the "Corbicula bed" rises slightly, and is finally cut off by the overlying Low Terrace gravels.



SECTIONS IN RUTTER'S PIT, NEAR CRAYFORD.—*A. L. Leach.*

Section 3 in the N.E. corner of "Rutter's" pit was next examined. Here the brickearth was distinctly seen to be cut off above by the Low Terrace gravels, the junction being formed by the contorted layer called "Trail" (Rev. O. Fisher). It was pointed out that wherever the Low Terrace gravel rests upon the brickearth, there are signs of disturbance and erosion, but the pronounced indents and folds are not everywhere so well seen as in this particular section. The origin of the "Trail" is not clearly established. Prof. Boyd Dawkins considered it a result of ice action—the grounding of ice masses, etc. He assumed the "Trail" to represent the Boulder Clay of the northern slopes of the Thames Valley, and was thus led to class the brickearths as Pre-Glacial. Geikie, Pocock, and others also suggest ice action, while F. C. J. Spurrell considers the deposit partly due to ice-movement, and partly to rain-wash over frozen soil, movements of thawing soil, etc. Several features in the actual sections are difficult to reconcile with any of these theories.

From "Rutter's" pit the party proceeded to "Furner's" pit near Slade's Green. Here the lower brickearth has become a very pebbly sand; the clayey brickearth is only about 8 ft. in thickness, and is deeply cut into by the "Trailed" Low Terrace gravels. In this pit the first Palæolithic flake ever found in the

Crayford District was discovered by the Rev. O. Fisher in 1870. It was associated with *Corbicula* and *Unio littoralis.*

The party examined two large blocks (each weighing over 2 cwt.) of light grey sandstone, lying on the floor of the pit. These were probably brought down the Thames by floating ice. Amongst the pebbles many sandstones, quartzites, sarsens, and Bunter pebbles were found with white quartz, jasperoid flint, and Lower Greensand Chert. The Director showed a portion of an igneous rock found by him recently in this pit. It contained rosy quartz crystals and a streaky black mineral, and had evidently travelled very far. Two most interesting "finds" were made by members of the party. Mr. H. W. Monckton picked up a pebble of Carboniferous limestone containing a coral which was identified by Mr. E. T. Newton as *Lithostrotion junceum.* Mr. R. H. Chandler found a well-worked flake in the "Trailed" terrace gravels. After glancing at the well-developed "Trail" the party climbed to the platform caused by recent excavations in the Low Terrace gravels. Here numerous large chalk flints, almost unrolled, were noted, and the whole appearance of the gravel was seen to differ greatly from the older deposit a few feet below.

As this was the last section included in the programme for the afternoon, a vote of thanks to the Director was carried on the proposition of Mr. H. W. Monckton.

While some members now returned to Erith; others walked on with the Director to look at "Stoneham's" pit, where the bones and teeth of the Pleistocene mammals have been found in large quantities. The site of the "Palæolithic floor" discovered by Mr. Spurrell was on the western side of this pit, which is further noteworthy as the place where Prof. Boyd Dawkins found the skull of *Ovibos moschatus.* This part of the pit is not worked now, but on the north side a few members collected fossils from a very rich part of the "Corbicula bed." The majority returned to Erith, and took tea at the "Wheatley Arms." On the way "Buckley's" pit at Erith was visited, and some large sarsen stones were found. Here the drift showed false-bedded sands with layers of flint gravel.

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EXCURSION TO BEDFORD.

SATURDAY, MAY 27TH, 1905.

Director: H. B. WOODWARD, F.R.S., F.G.S.

Excursion Secretary: H. KIDNER, F.G.S.

Report by THE DIRECTOR.

THE members arrived at Bedford at 11.15 a.m., and were joine[illegible] by Mr. R. Hill, President of the Bedford Literary and Scientifi[illegible] Institution, Mr. J. Hamson and others, so that the party consisted of about twenty-five. They were driven first of all throug[illegible] the town, and about a mile northwards to Mr. Charles Franklin' [illegible] pits by the waterworks.

In an excavation close to the Pumping-station the Grea[illegible] Oolite Limestone, the lowest formation exposed in the neighbour[illegible]hood, was seen to a depth of about 12 ft., overlain by 9 ft. o[illegible] Great Oolite Clay, by the thin band of Cornbrash (locally terme[illegible] "Pendle"), and by the clays at the base of the Kellaways Bed[illegible] The clays served to protect the rock-beds from weathering, an[illegible] both Great Oolite and Cornbrash were of a dark bluish-gre[illegible] colour with rusty joint-faces. In the highest of the series [illegible] excavations the loams and sands of the Kellaways Beds wit[illegible] huge "doggers" of calcareous sandstone were well expose[illegible] Thus in a thickness of about 50 ft. there were representatives [illegible] formations that in the Cotteswold Hills attain about 300 ft. Th[illegible] Great Oolite of Bedford was a poor formation compared wi[illegible] that at Bath and Minchinhampton, and the same might be sa[illegible] of the Great Oolite Clay when compared with the Forest Marbl[illegible] while the Cornbrash was reduced to a foot or two. Neverthele[illegible] the strata were of considerable interest, and the Kellaways Be[illegible] were as well developed perhaps as in any part of the count[illegible] The Great Oolite was here burned for lime, and the overlyi[illegible] clays and loams were used for brick-making. The Great Ool[illegible] was also locally of great importance as a water-bearing formati[illegible] Interbanded as it was with marly layers, and being little m[illegible] than 25 ft. thick, it seemed incapable of yielding a large sup[illegible] from the direct rainfall on its outcrop. Nevertheless from t[illegible] adjacent Pumping-station, as much as a million gallons of wa[illegible] had been daily obtained. That this supply was connected w[illegible] the great body of water which flowed down the Ouse Va[illegible] could not be doubted. From Sharnbrook to Bedford, a dista[illegible] of seven miles in a straight line, the Ouse flows in a serpent[illegible] course over a foundation of Great Oolite; the broad valley being occupied by Alluvium, and also by river gravel, much of which rests directly on the Oolite. Where the Oolite rises above the banks of the river, springs issue from it; but generally speaking across the valley the water-level in the porous strata is practically the river-level. When the river is low, springs issue into it from ower levels than usual along its borders; and when in flood the river naturally raises the level of water in the bordering porous strata. A great quantity of water is thus moving down the valley—whether in the open stream or still more sluggishly in the strata.

Bedford has derived its water-supply from a well sunk about 17 ft. below the ordinary river-level, with headings, in the Great Oolite Limestone. The site is adjacent to the river, and the rest-evel in the well coincides with the river-level. Yet that there is no immediate connection between the river and the well is shown by the fact that the water in the well and headings, always considerably lowered by pumping, is but slowly replaced; and in imes of drought it has not always been possible to get the necessary quantity of about one million gallons a day, without aking water direct from the river. These facts indicate that the water in the well must travel some distance through fissures in he Great Oolite Limestone, and that it probably comes from reas higher up the valley where broad tracts of gravel rest on the mestone, and where the underground stores of water are in all robability connected more or less directly with the water in the ver. A new well with heading had recently been made to the outh of the Pumping-station, and a considerable increase in the upply of water had been reported. This well appeared to be tuated on the south side of a fault, having a downthrow on the outh of 8 or 10 ft.; and this dislocation was stated to be within few feet of the well.* It is not improbable that there is a ouble or trough fault which lets down a strip of limestone in the rea north of the Bedford and Bromham high-road. Further tention was called to this.

After driving through the village of Clapham the party opped at a gravel pit on the road to Oakley, a short distance to he east of the Midland Railway. Here a small anticline in the Great Oolite Limestone, and overlying Great Oolite Clay, was xposed in the midst of the gravel. An account of this section ad been published by the Director. The trend of the fold was N.N.W., and S.S.E., and therefore contrary to that of the minor olds which affect the Oolitic rocks of the district, and serve to counteract the general dip of these strata between Sharnbrook and Bedford. The gravel was largely composed of pebbles of Oolitic limestone, with also quartz, quartzite, jasper and flint. From the upper layers the limestone-pebbles had been dissolved, so that a brown stony loam with only siliceous stones filled "pipes" in the white gravel beneath.

The party now proceeded to Oakley Bridge, where Mr. R. Hill

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* See *Bedfordshire Times*, also *Bedfordshire Standard*, of May 26th, 1905.

drew attention to a flood-mark 6 ft. above the floor of bridge; date, November, 1823. After crossing the Ouse party were driven through Bromham, where they dismissed vehicles. In the road-cutting south-west of Bromham Park Great Oolite Limestone was seen to dip northwards at an angl 5 or 6 degrees, a disturbance possibly connected with the near the Waterworks. The Swan Inn at Bridge End, Bromh was next visited, after which the party were conducted to limestone-quarry about half a mile distant on the roa Stagsden. Here a succession similar to that seen in Franklin's pit, from the Great Oolite Limestone to the C brash and Kellaways Clay, was opened up. *Ostrea Sowe* was abundant in the Great Oolite, which comprised ne 12 ft. of shelly blue-hearted limestones with clay-partings, layers of stone being wedge-bedded, and some of them minu current-bedded.

The Great Oolite Clay above was a dark and occasio coloured clay, with ironstone nodules at the base.

The Cornbrash, more attenuated than by the Waterw occurred in nodular masses, and yielded *Ostrea flabelloides*, *L pectiniformis*, and *Waldheimia lagenalis*, identified by Mr. E Newton. A point of considerable interest in this pit was way in which the beds of Great Oolite Limestone became n and more weathered towards the outcrop, passing into ru then into crumbly marl, and finally into a brown calcareous l which was washed down the slopes. Elsewhere the joints in Great Oolite Limestone were much weathered, and the fiss and even minor cracks were filled with clay. In the Great O Clay above there were open cracks extending 2 or 3 ft. dow the limestone, and thus in dry weather access was formed for which subsequently carried clay into the fissured limestone be

There were indications also of slight unconformity between Great Oolite Clay and Limestone, the former being seen to lap the higher layers of limestone.

The members now turned their steps towards Bedford, ing the old bridge at Bromham, where attention was called t meandering of the river. It was remarked that rivers in old age get sluggish, and have a tendency to wander from si side, widening because they cannot deepen their channels. once the tendency to meander has been developed the pr continues, the curves become more and more pronounced, they are gradually shifted down the course of the river. dealing with this subject Messrs. T. C. Chamberlin and Salisbury refer to the possible influence of the earth's rotati initiating the serpentine curves.*

Thence the party walked on to the large gravel-pit in Deep Spinney at Biddenham, on the high road to Bed

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* See "Geology—Processes and their Results" 1905, pp. 180-184.

Here about 18 ft. of gravel was exposed, the upper part decalcified and "piped" like the gravel near Oakley, while a good deal of the carbonate of lime had been re-deposited as a coating or cement in the white gravels.

It was at this locality that James Wyatt found the first palæolithic flint implements that were obtained in this country after their great antiquity had been established. Lyell,* writing in 1861, remarked, "I am laid up for a day or two after an excursion to Bedford with Prestwich and Evans, to see a section where a Mr. Wyatt, editor of the Bedford provincial newspaper, has just found two fine hatchets of the true Amiens and Hoxne type. They occurred in working a gravel pit at Beddingham" (Biddenham).

As pointed out by Mr. J. Hamson, the pit in which Mr. Wyatt discovered the implements was the old gravel-pit a little to the north-west on the other side of the high road. The implements were found in the base of the gravel at a depth of about 12 ft., just above the limestone-rock. Wyatt procured also many land and freshwater mollusca, and remains of *Elephas antiquus*, *E. primigenius* (Mammoth), *Equus*, *Bos*, *Cervus*, *Rhinoceros*, and *Hippopotamus*. Portions of an elephant's tusk were brought before the party by a workman. From time to time implements are now obtained at Biddenham Pit, but they are more often found at Kempstone, on the southern side of the river, and those purchased from the workmen may have come from one or other locality. Derived fossils, such as Saurian bones and Jurassic fossils, are not uncommon.

Attention was now directed to a "cave" which had been found while working the gravel early in the month of April. It was about 5 ft. in height, length, and breadth; there was no artificial entrance, and no evidence of any human workmanship. The cavity had been boarded up, and through the courtesy of the proprietor, Mr. G. T. Jarvis, the members had the opportunity of seeing it uncovered.

It was evidently similar in character to cavities described by Sir John Evans in the valley gravel of the Little River Ouse in Norfolk; these had been proved to arise through the sinking of material into a "pipe" in the Chalk.† In the present case it seemed most probable that material had "caved in" or tumbled into a fissure in the Great Oolite Limestone below.

Not far away, in another part of the pit, the limestone was exposed beneath the gravel to a depth of 10 ft. or more in a large circular hole, the beds occurring in solid layers with not many joints and with clayey and marly partings not wholly impervious. No water was visible at the bottom. The position of this limestone was rather above the level where it might have

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* "Life, Letters, and Journals," vol. ii, p. 344.

† *Geol. Mag.*, 1868, p. 443.

been expected, and tended to confirm the view that there was an east and west fault to the north of the pit—perhaps the trough fault to which reference was previously made.

Since the date of this visit Mr. G. T. Jarvis (writing June 3rd) states that he proposed to sink below the cave and open up a well, but after excavating the loose gravel and clay for 4 or 5 ft. down to the rock, he encountered a fissure 10 to 12 in. wide in the limestone.

The party were now conducted through the picturesque village of Biddenham to Bedford. Here Mr. A. E. Hawkins, who had joined the party at Biddenham Gravel-pit, kindly invited the members to see the Museum belonging to the Bedford Modern School. This contained a good general collection of fossils, also many local specimens from the Jurassic Rocks and Mammalian remains from the Valley Gravels, which were of special interest. By invitation of Mr. W. Davis, the fine collection of local flint implements in the Bedford Literary and Scientific Institute was afterwards examined. After tea at the Harpur Restaurant several members visited the Bunyan Meeting House, and were much interested in seeing the relics of the immortal writer there preserved. The party returned to London by the 7.36 p.m. train.

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[*] "Life, Letters, and Journals," vol. ii, p. 344.

[†] *Geol. Mag.*, 1868, p. 443.

into paving-setts and curb-stones. One of these blocks was seen *in situ* in a pit about 20 ft. deep, embedded in the clay and flints, which is probably a disturbed mass derived partly from the Clay-with-flints proper, and partly from formerly existing Tertiary Beds, as several Tertiary Pebbles were noticed among the heaps of stone dug out of the pit, and in association with the sarsens.

Proceeding thence to the hamlet of Speen, a halt was made for tea at the King William IV. Inn and afterwards the members examined several large excavations at Walter's Ash, on the northern part of Naphill Common. Here there were large pits, some 40 to 50 ft. deep, in brown-bedded brickearth overlaid by a stiffer brown and bluish-grey clay, with here and there irregular beds of Clay-with-flints, occasional masses of mottled clay derived from the Reading Beds, and greywethers of varying sizes and in all sorts of positions. Two industries are carried on here, that of brick-making, and that of dressing the stones for building and paving purposes. In one instance, at least, the huge greywethers presented the appearance of having subsided with other accumulations, mostly mottled clay and subangular flints, into a huge pipe in the Chalk, as described by the Rev. E. C. Spicer,[*] although the Chalk was not visible in the pit. The greywethers however, were embedded in brickearth or clay and flints indifferently, and the entire accumulation was regarded by Mr. Woodward as a wreck of Reading Beds and Clay-with-flints. A few outliers of Reading Beds still remain on the Chalk tracts away from the main mass, and no doubt the strata formerly extende over a wide area of the Upper Chalk. The destruction may hav taken place by flood-waters arising from the melting of ice durin the Glacial period.

Mr. Herries agreed with Mr. Woodward, and though he thoug Mr. Spicer's theory that the occurence of the buried sarsen stone was to be accounted for by swallow-holes in the Chalk might some instances be true, he did not think it was of general app cation. It would, he said, be a curious coincidence that convenient swallow-hole should always be ready to absorb a sarsen. Moreover, in some of the pits seen by the members t brickearth was very evenly stratified, and had not at all t appearance of having gone through the disturbance that would involved in subsiding into a swallow-hole. He thought possible that the brickearth (which was derived from n destroyed Tertiary outliers) had been laid down in still wat such as small lakes, into which the sarsen stones had fallen, a that this was followed by a more tumultuous rush of water whi had brought the irregular clays and flints and some sarsen sto on the top. He regretted the absence of Mr. Spicer, who thus unable to present his views on the spot.

From Walter's Ash, by way of Bradenham, to the new sta

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[*] *Quart. Journ. Geol. Soc*, vol. lxi, p. 39. 1905.

at Saunderton, the members had to walk at an accelerated pace in order to catch the 6.15 train to Paddington. On the way some large blocks of pudding-stone were noticed on the village green of Bradenham.

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EXCURSION TO THE ISLE OF THANET.

WHITSUNTIDE, 1905.

JUNE 10TH TO JUNE 13TH.

Director: W. WHITAKER, B.A., F.R.S., F.G.S., AND A. W. ROWE, M.B., F.G.S.

Excursion Secretary: G. W. YOUNG.

THE official party left Holborn Viaduct by the 5.10 p.m. train on Friday, June 10th, and on arriving at Margate proceeded to the headquarters at the Hereward Boarding House, Cliftonville.

SATURDAY, JUNE 10TH.

Report by MR. WHITAKER.

The party, numbering twenty-five, left Margate by the 9.14 train for Herne Bay, and then walked at once to the coast. On getting beyond the town the general geological structure of the coast was explained. This is very simple, the beds steadily but slowly sinking westward; so that whilst at Sheppey, to the west, the London Clay at the highest point is capped by Bagshot Sand, in an easterly course to the Reculvers, the beds beneath the London Clay rise up and soon appear in the cliffs, and beyond the Chalk also rises and at last appears at the western end of the Isle of Thanet.

The three divisions of the Lower London Tertiaries were successively studied; but as the details of them have often been printed there is no occasion to reproduce them here. The Oldhaven Beds (light-coloured sand with pebbles at the base) were first seen, cropping up from beneath the London Clay, and many fossils were got in the masses of iron-sandstone and sandstone, so frequent in them here, and so well to be seen in fallen blocks on the foreshore. The Woolwich Beds (also sand) were then noticed.

The loss of coast between Herne Bay and Oldhaven Gap was noticed, the cliff at the entrance to the latter place having altered a good deal. Here, through the kindness of Miss Monckton, we walked up the ravine or chine, which is a good illustration of the erosive power of a small stream. On the western side the little valley is cliff-like, whilst the eastern is a broken slope; this is probably due to the slight westerly inclination of the beds.

It was pointed out how in these parts there is no good division between the Woolwich and the Thanet Beds, the upper part of the latter consisting of a light-grey sand of much the same character as that of the former. This is a local condition, however, due in part to the absence of pebbles at the base of the Woolwich Beds, and, perhaps, also to the top part of the Thanet Beds being higher in the series than the Thanet Sand of Central and Western Kent, etc. In this tract, taken alone, no division would be made, structurally or palæontologically, between the two divisions, both consisting of sand with similar marine shells.

A halt was made at the Reculvers, and the evidence of loss of land given by the destruction of part of the Roman station was noticed.

The walk was continued along the shore at the edge of the marshes, which in Roman times were partly a water-channel, for the protection of the entrance to which the Roman station must have been made. Some opportunities were given for studying the movement of shingle and the way in which part of it sometimes shut in lagoons of water.

On reaching Thanet, Chalk was at once found, and, whilst many of the party carried out the programme by going to Birchington and returning by train, others (including the President and the Director), tempted by the weather, and finding that there was plenty of time, walked on to Margate, and had good views of the effects of fairly persistent and regular jointing on the shape of the cliffs, with hollows and small stacks of Chalk surrounded by the sea.

On the following day some members went to Canterbury in the morning, and were met at the station by Mr. W. Cozens. He took them to his sand-pit, close by and west of the Whitstable railway, the section in which is an improvement on that formerly shown in the adjoining pit touching the railway.

The newer section shows the junction of the London Clay with the Oldhaven Beds, which was not seen before, and has not been recorded. It comes exactly where it ought to, that is to say, where it was shown on the Geological Survey Map, the maker of which therefore was not displeased. The Oldhaven Beds here differ in one particular from those shown on the coast; the pebble-bed at the bottom is for the most part replaced by a bed of ironstone about 3 ft. thick, but there are pebbles also in places. Beneath, the light-grey sand of the Woolwich Beds is shown, and it is here very glauconitic, giving a green streak on crushing.

Then a visit was paid to the brickyard a little southward, where there is a good section in a terrace of the River Drift of the Stour. At top there is brown brickearth, and below this gravel of the usual character (flints and flint pebbles). Mr. Cozens told us that he had made a boring through this, and had found clayey sand or sandy clay with shells, clearly part of the Thanet Beds.

In the afternoon the castle was visited, and the beautiful garden of the Dane John, bounded by the old wall. Finally the cathedral was seen.

MONDAY, JUNE 12TH.

We went at 9.30 by electric tram to Ramsgate, and then walked past the harbour and along the shore. The general absence of shingle or sand along the shore was noticed, and the particular presence of alluvial clay on the foreshore was abundantly evident. The cliffs at first are in the flinty chalk of the *Micraster cor-anguinum*-zone, but at Pegwell the beds sink westward, and the higher divisions, the *Uintacrinus*-band and the *Marsupite*-band come on above. There are many small caves along the foot of the cliffs, often at small faults or joint-planes.

The cliffs get lower, however, and at top, westward of Pegwell, there is a capping of surface-loam several feet thick.

Owing to the westerly inclination of the beds along the coast-section, the Thanet Beds soon come on over the Chalk westward of Pegwell Bay. The junction was well shown for a length of several chains. At first it was seen to be very irregular, partly perhaps from disturbance of the beds (the appearance of which led to the junction being marked as a faulted one on the Geological Survey Map), but partly, no doubt, to the dissolution of the Chalk by percolating water. Very soon, however, in our eastward course, the junction took on its usual even character. It is notable that when the Director mapped this particular piece of ground many years ago, he had to dig out the junction now so clearly shown, by the cutting back of the cliff.

Higher beds of the Thanet Series come on westward, with layers of shells, until at last beds with doggers or stones, like those at the base of the Reculvers section, are to be seen at the top, so that the two sections supplement one another and open out the whole of the Thanet Beds.

The surface-loam occurs over nearly the whole of the Thanet

Beds, and might easily be taken, by the casual observer, as an upward continuation of them.

The chalk beneath the Thanet Beds is somewhat rubbly in appearance, though it has not been moved, and its joint-planes are apparent, and just to the east, under the loam and gravelly earth, what can be seen of it is still more rubbly-looking.

The walk was then extended along the low ground southward, largely consisting of shingle, which, however, forms strips piled up in the reverse direction to what now holds, stretching from the land southward, whereas now the shingle moves northward, thus pointing to a different condition of things in past (? Roman) times.

At Stonar Cut it was pointed out how the formation of this long bank of shingle had forced the Stour southward to Sandwich, whence it turns northward, along the outer border of the shingle, coming back to within about a sixth of a mile of its course on the inner side of the shingle, after a flow of 5 or 6 miles.

At the cut the river was crossed by ferry, and the walk extended to Richborough, where the fine remains of the Roman Castle were seen, and some underground passages were inspected. This castle, not far from the inner side of the shingle-bank, commanded the sea approach by the Stour as Reculvers commanded that by the Wantsome.

The cutting along the eastern face of the hill, which once gave a fine section of fossiliferous Thanet Beds, is now overgrown, and nothing but the surface-deposit, fairly full of the signs of human occupation, with a little of the underlying sand, could be seen.

We then walked across the marsh to Sandwich, and at the outskirts of the town were caught in a thunder-shower, the only rain-storm experienced during the whole of the excursion.

After tea the return was made by train, part of the old earthen wall of the town being seen on the way.

TUESDAY, JUNE 13TH.

Director: DR. A. W. ROWE, F.G.S.

(*Report by* THE EXCURSION SECRETARY.)*

The party assembled at Hodges' Flagstaff, where they were met by Dr. Rowe and Mr. C. D. Sherborn, and descended to the shore at Sackett Gap. Dr. Rowe explained that in the chalk cliffs of this part of Thanet we had a splendid exposure of the *Marsupites*-zone, extending on both sides of Margate, to

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* For full account of this section see Dr. Rowe's paper in *Proc. Geol. Assoc.*, vol. xvi, p. 294.

Birchington on the west and Kingsgate on the east, a distance of seven miles. The chalk is very soft and white, with very few flints. Fossils are abundant and easily cleaned, but they must be soaked in water, which should be changed daily, for at least three weeks, to get rid of the salt. He next pointed out the "Bedwell-line," an ill-defined band of scattered flint nodules, here about 30 ft. from the base of the cliff. It is a valuable horizon, as it marks the junction of the two "bands" into which Dr. Rowe subdivides this zone, the *Marsupites*-band above and the *Uintacrinus*-band below.

After the Director's opening remarks we proceeded eastwards along Palm Bay, and at once commenced to collect. The typical fossils were soon found: *Actinocamax verus*, the nipple-shaped head of *Bourgueticrinus*, *Uintacrinus*, *Ammonites leptophyllus*, *Porosphæra globularis* (very large), *P. pileolus*, *Serpula turbinella*, *S. plexus*, *Kingena lima*, *Lima hoperi*, and our attention was specially directed to the two shape-variations of *Echinocorys vulgaris*, characteristic of the zone. The pyramidal shape-variation is abundant throughout the face, and is displayed as a rich band immediately below the "Bedwell-line."

We next proceeded to Foreness Point, where the Bedwell-line sinks to the shore, and the *Marsupites*-band comes within reach. Several fine examples of *Marsupites testudinarium* were found, and detached plates were very numerous, and well weathered out. *Act. granulatus*, another characteristic fossil, was also found here.

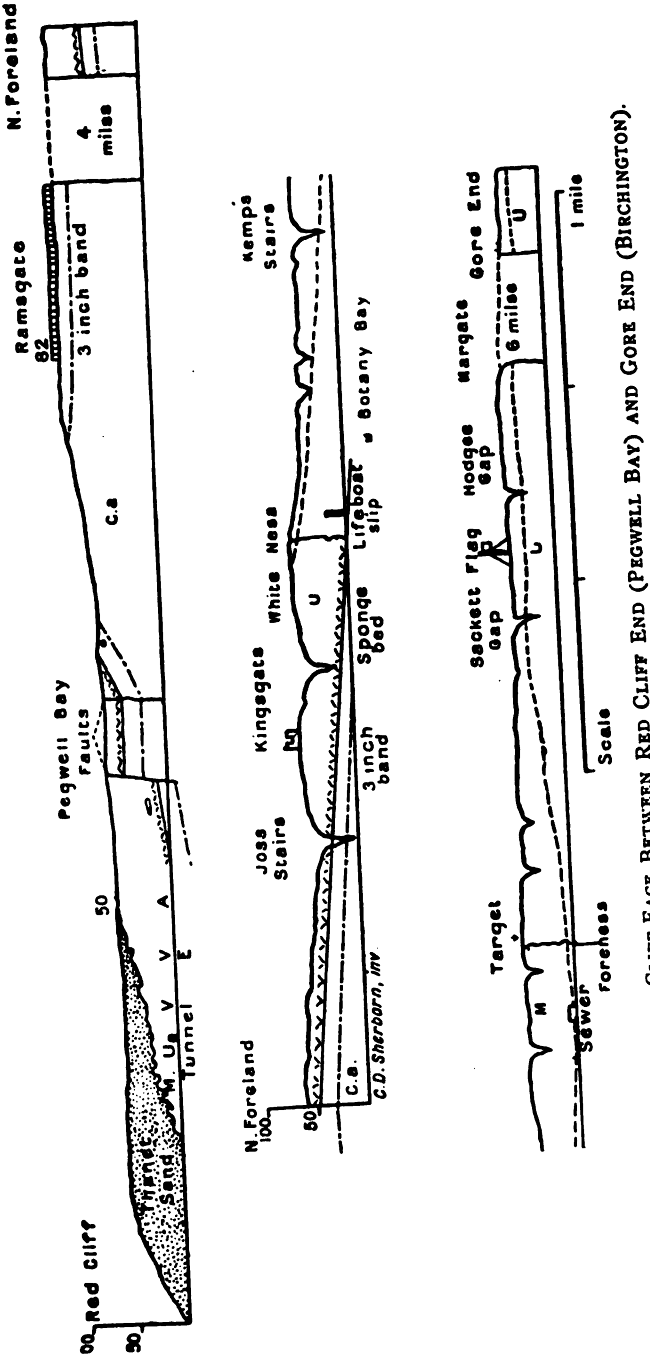
Beyond Foreness the Bedwell-line soon rises again, and we found ourselves once more in the *Uintacrinus*-band, from which we continued to collect. All along the section the Chalk is remarkably jointed, showing wall-like vertical surfaces running about N.W. and S.E., and many caves have been excavated along these joint-planes.

After lunch we proceeded direct to White Ness, where the Director pointed out the "Barrois' sponge-bed" rising from the shore. This marks the base of the *Marsupites*-zone, which is succeeded by that of *Micraster cor-anguinum*. Above the "Barrois' sponge-bed" there is a remarkably persistent thin but closely packed layer of *Echinoconus conicus*.

The latter part of the day was given up to an examination of the *M. cor-anguinum*-zone, which is well displayed under Kingsgate Castle and at the North Foreland.

Dr. Rowe explained that for the next ten miles, passing Broadstairs and Ramsgate as far as Pegwell Bay, the cliffs are cut in the *M. cor-anguinum*-zone. In this zone flint-bands are numerous and at fairly regular intervals, while the Chalk is somewhat firmer than in the zone above.

Our attention was here drawn to the "Whitaker 3-in. band," a very conspicuous feature. It is a compact layer of tabular flint,



SECTION ALONG THE CLIFF-FACE BETWEEN RED CLIFF END (PEGWELL BAY) AND GORE END (BIRCHINGTON).

A. ■ Ammonites ([illegible]).

uilding-stone and for lime-burning, the material being exported y water.

Near the foot of the slope on the northern side of the ridge e Directors had recently discovered a small exposure of Chalk ock in a road cutting. The characteristic features of this ratum—hard cream-coloured rock with green-coated nodules—ere noted, and a few fossils collected. The following have een obtained by the Directors:

mmonites (*Pachydiscus*) *peramplus*, Mant.
caphites Geinitzi, d'Orb.
leurotomaria perspectiva, Mant.
Turbo gemmatus, Sow.
Trochus berocscirensis, Woods
ardium sp.
noceramus sp.
Nucula sp.
Rhynchonella plicatilis, Sow.
Terebratula semiglobosa, Sow.
Terebratula carnea, Sow.
Serpula sp.
Micraster cor-bovis, Forbes.
**Micraster* sp.
Parasmilia centralis, Mant.

Crossing the river by Marlow Bridge and passing through the own, the party continued their walk up Oxford Lane, where a ecent widening of the roadway at the first bend has exposed a ood section, some ten feet in depth, of rather coarse flint and uartzite gravel, with a loamy matrix and seams of chalky matter, elonging to an obscure river-terrace about 100 ft. above the hames. A little farther up the lane older cuttings show a more layey drift, containing angular flints and chalk rubble, and ossessing a rude stratification obviously due to the creep and ash of the material down the slope in which this part of the road sunk.

At a point nearly opposite the entrance to the Waterworks, the pmost layer of the Chalk Rock, with its characteristic green-ated nodules and a few fossils, appears in a small excavation st above the level of the road and about 100 feet higher than e similar section mentioned above in Quarry Wood, a mile and half to the south-east.

Having examined these sections the members entered the Vaterworks quarry, the floor of which in part coincides with the op of the Chalk Rock. The face of the pit shows about 60 ft. f chalk; white, with frequent bands of nodular and tabular flint n the upper two-thirds; greyish, lumpy, and containing small cattered flints and a few tabular seams in the lower third. One onspicuous band of tabular flint occurs about 10 ft. up and orms a useful datum line.

The beds in this section have been assigned both to the lower†

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* A small form, common, but seen only in section.

† "Geology of London," *Mem. Geol. Survey*, vol. I, p. 76.

a terrace reaching southward to beyond Maidenhead, at an average level of 75 ft. above the Thames. On this occasion the pit was not being worked, and only a few flakes and broken implements were found, but on the return journey in the evening some fairly good specimens were obtained from a workman who met the train at Cookham Station. From Cookham Rise the field-path was followed over the hill to the large chalk quarry on Cookham Dean common. In this pit, which is about 70 ft. deep, small nodular flints occur in regular layers, many of them being cavernous and containing "meal" rich in small fossils. In some places near the bottom the flints are so close together as to form intermittent tabular layers. The chalk itself was found to be rather poor in fossils, the most abundant being spines of *Cidaris clavigera*. The Directors considered that, from the position of the pit, the floor being at least 100 feet above the level of the outcrop of the Chalk Rock a short distance to the north, and also from the character of the fossils, the chalk here belonged to the lower part of the zone of *Micraster cor-anguinum*. The following is a list of fossils obtained by the Directors from this pit, chiefly from the lowest 10 feet:—

Inoceramus sp. (fragments).
Pecten cretosus, Defr.
Plicatula sigillina, S. P. Wdw.
Kingena lima, Defr.
Rhynchonella sp.
Berenicea (several species).
Clausa francqana, d'Orb.
Clinopora lineata, Beissel.
Diastopora sp.
Entalophora echinata, Reuss.
Entalophora virgula, Hag.
Petalopora costata, d'Orb.
Spiropora verticillata, Goldf.
Stomatopora granulata, Edw.
Truncatula sp.
Eschara sp.
Membranipora monilifera, d'Orb.
Membranipora ovalis, d'Orb.
Vincularia sp.
Serpula granulata, Sow.
Serpula ilium, Sow.
Serpula turbinella, Sow.
Cidaris clavigera, Kœnig.
Cidaris perornata, Forbes.
Cidaris sceptrifera, Mant.
Cidaris serrifera, Forbes.
Galerites albogalerus, Leske.
Micraster (fragments).
Asteroid ossicles.
Bourgueticrinus ellipticus, Miller.
Pentacrinus.
Parasmilia centralis, Mant.
Porosphæra globularis, Phil.
Porosphæra patelliformis, Hinde.
Doryderma ramosum, Mant.

The road and footpath were then taken across the Quarry Wood ridge, from the top of which fine views were obtained of the Thames Valley and the Buckinghamshire hills, and the position of the now overgrown chalk quarry, which had given its name to the locality, was pointed out close to the right bank of the river. In former times much chalk was quarried here for building-stone and for lime-burning, the material being exported by water.

Near the foot of the slope on the northern side of the ridge the Directors had recently discovered a small exposure of Chalk Rock in a road cutting. The characteristic features of this stratum—hard cream-coloured rock with green-coated nodules—were noted, and a few fossils collected. The following have been obtained by the Directors:

Ammonites (*Pachydiscus*) *peramplus*, Mant.
Scaphites Geinitzi, d'Orb.
Pleurotomaria perspectiva, Mant.
Turbo gemmatus, Sow.
Trochus berocscirensis, Woods
Cardium sp.
Inoceramus sp.
Nucula sp.
Rhynchonella plicatilis, Sow.
Terebratula semiglobosa, Sow.
Terebratula carnea, Sow.
Serpula sp.
Micraster cor-bovis, Forbes.
[*]*Micraster* sp.
Parasmilia centralis, Mant.

Crossing the river by Marlow Bridge and passing through the town, the party continued their walk up Oxford Lane, where a recent widening of the roadway at the first bend has exposed a good section, some ten feet in depth, of rather coarse flint and quartzite gravel, with a loamy matrix and seams of chalky matter, belonging to an obscure river-terrace about 100 ft. above the Thames. A little farther up the lane older cuttings show a more clayey drift, containing angular flints and chalk rubble, and possessing a rude stratification obviously due to the creep and wash of the material down the slope in which this part of the road is sunk.

At a point nearly opposite the entrance to the Waterworks, the topmost layer of the Chalk Rock, with its characteristic green-coated nodules and a few fossils, appears in a small excavation just above the level of the road and about 100 feet higher than the similar section mentioned above in Quarry Wood, a mile and a-half to the south-east.

Having examined these sections the members entered the Waterworks quarry, the floor of which in part coincides with the top of the Chalk Rock. The face of the pit shows about 60 ft. of chalk; white, with frequent bands of nodular and tabular flint in the upper two-thirds; greyish, lumpy, and containing small scattered flints and a few tabular seams in the lower third. One conspicuous band of tabular flint occurs about 10 ft. up and forms a useful datum line.

The beds in this section have been assigned both to the lower[†]

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[*] A small form, common, but seen only in section.

[†] "Geology of London," *Mem. Geol. Survey*, vol. I, p. 76.

and to the upper[*] portions of the zone of *Micraster cor-testudinarium*, but actually belong partly to that zone and partly to the zone below.

Owing to the comparative scarcity of distinctive organic remains, and to the fact that the higher parts of the section are generally inaccessible, the exact position of the junction of the *Holaster planus*-and *M. cor-testudinarium*-zones has not yet been determined. A fair number of fossils are obtained by the quarry-men, but a rather close search is necessary for the detection of the all-important *Micraster* and its associate guide fossils, *in sitû*. The specimens of *M. præcursor* so far forthcoming from the base of the section are all of the *H. planus*-zone types, with sutured, or feebly-inflated-areas and those found a little higher up, but still below the tabular band above referred to, have moderately, to distinctly, inflated areas. From 1 to 3 ft. above the tabular flint band a few tests with areas of the strongly inflated type have been found by the Directors, while from the higher beds the quarry-men have obtained examples with the subdivided ambulacra and other essential features of the *M. cor-testudinarium*-zone types, including the name fossil. The gibbous form of *Echinocorys scutatus* is very common in the *H. planus* beds, and *Holaster placenta* scarcely less so, but *H. planus* itself has not been observed. The following is a list of fossils either found by the Directors themselves or obtained from the workmen who collect under their instructions. All of them come from the lower two-thirds of the section, the upper third not having been worked for many years.

Lamna sp.
Ptychodus latissimus, Ag.
Inoceramus sp. (v.c.).
Spondylus spinosus, Sow (v.c.).
Crania egnabergensis, Retz.
Terebratula semiglobosa, Sow (v.c.).
Terebratula carnea, Sow.
Terebratulina striata, Wahl.
Berenicea sp.
Proboscina sp.
Stomatopora granulata, Edw.
Meliceritites Lonsdalei, Greg.
Membranipora (*Hippothoa*) *elegans*, d'Orb.
Enoploclytia Leachi, Mant.
Serpula cincta, Goldf (c).
Serpula sp. (?)
Echinocorys scutatus, Leske.
Infulaster excentricus, Rose (v.c.).
Micraster cor-testudinarium, Goldf.
Micraster præcursor, Rowe (c).
Holaster placenta, Ag. (c).
Cidaris sceptrifera, Mant.

The lower beds contain also many sponges, chiefly in the form of ferruginous casts.

When the members had satisfied themselves as to the *H. planus*-age of the lowest beds here, and had awarded a vote

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[*] "Cretaceous Rocks of Britain," *Mem. Geol. Survey*, vol. iii, p. 217.

of thanks to the Directors on the proposition of Mr. E. T. Newton, F.R.S., they returned to Marlow for tea, and left by the 7.30 train.

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1897. TREACHER, LL.—"Excursion to Cookham." *Proc. Geol. Assoc.*, vol. xv, p. 101.
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THE GEOLOGY OF CENTRAL WALES.

With special reference to the Long Excursion for 1905.

By HERBERT LAPWORTH, B.Sc., F.G.S., A.M.I.C.E.

(*Read July 7th, 1905.*)

DEFINITION.

THE area described in the present paper may be defined as that portion of Central Wales lying from north to south between Machynlleth and Caermarthen, and from east to west between Builth and the coast line of Cardigan Bay. It embraces the County of Cardigan, with a surrounding strip in the Counties of Caermarthen, Radnor and Montgomery.

This area may be detected at once on the Geological Survey Maps, in which this piece of country is shown coloured a pale pink, and stands out prominently in the surrounding darker colours. The total area is about 1,800 square miles, or nearly a quarter of the entire area of Wales.

PHYSICAL FEATURES.

With the exception of the bordering country, and in places where great grit formations meet the softer shaley groups, the scenery is more or less one uniform type.

The surface features are those of bleak moorlands in the form of parallel ridges, elongated along the line of strike with minor parallel crests, everywhere pierced through by cleaved slates or thin grit beds. The valley bottoms are often well wooded; and in the deep gorges, where hard and soft rock-groups are in contact, as for example at the Devil's Bridge and Caban Côch, the scenery is bold and strikingly beautiful; but above the valleys the general type, though having a beauty of its own, is desolate and monotonous.

Two widely-separated railways border the heart of this area, one running from Aberystwith to Caermarthen, the other from Newtown to Builth. Between these two railways the country appears almost devoid of agricultural value. It supports, consequently, a sparse population, who derive some slight benefit from an almost extinct lead-mining industry.

GEOLOGICAL HISTORY.

It may be stated here at the outset that at the present time, although much information has been collected, very little indeed is known of the detailed geological structure of Central Wales.

The country has been avoided by geologists, chiefly, it is to be supposed, because of its monotony and the rarity of fossils with the exception of graptolites, and even these are difficult to extract, owing to the prevalent cleavage of the rocks. But

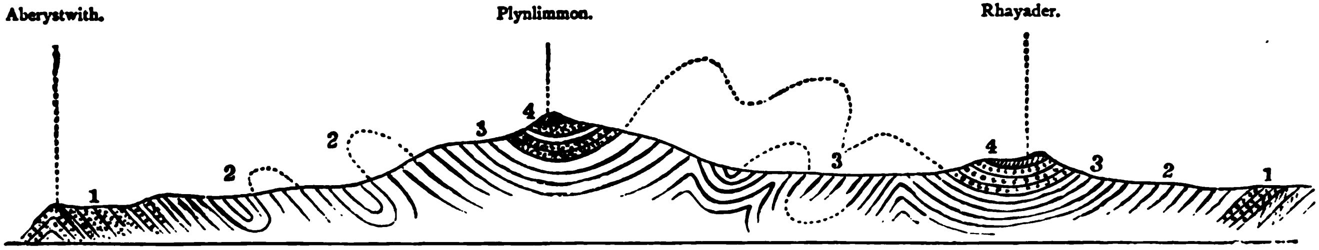


FIG. 2.—DIAGRAMMATIC SECTION OF CENTRAL WALES.—*W. Keeping.*

1. Aberystwith Grits. 2. Metalliferous-slate Group. 3. Rhayader Pale Slates. 4. Plynlimmon Grits.

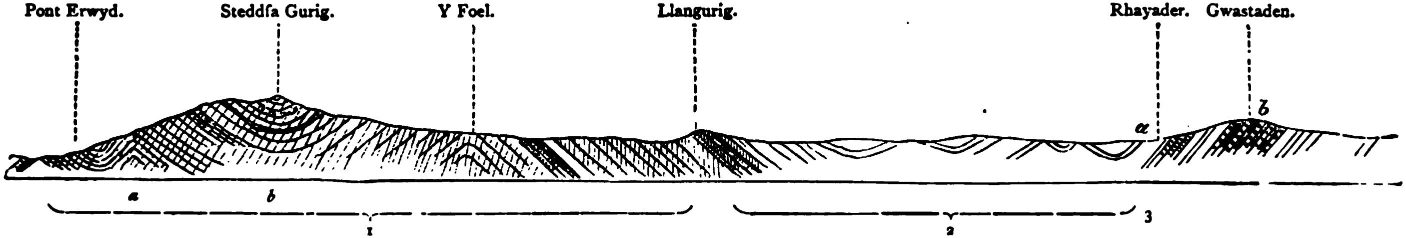


FIG. 3.—SECTION FROM PONT ERWYD TO RHAYADER AND GWASTADEN.

1. Metalliferous Slate Series with a few thin grits. 2. Drift-covered country. 3. Pale Slates. 4. Conglomerates.
a. Inversions. *b.* Plynlimmon Synclinal.

with these conditions favourable, the rocks are often so violently folded and inverted that it is only by working out a small area in detail that really satisfactory results can be obtained.

The first to attack Central Wales was Murchison, who, in 1839, placed the rocks of this area in the Cambrian System. Eight years later (1847) Sedgwick attempted a broad grouping, and founded his "Aberystwith" and "Plynlimmon" Groups, together with the "Rhayader Pale Slates." He adhered, however, to Murchison's opinion as to their antiquity.

About 1850 the Geological Survey Maps of the district were published, prepared from the surveys of Ramsay and Aveline. The greater part of the region was indicated as Lower Llandovery, on the ground that the Survey officers had actually discovered Lower Llandovery fossils within its limits.

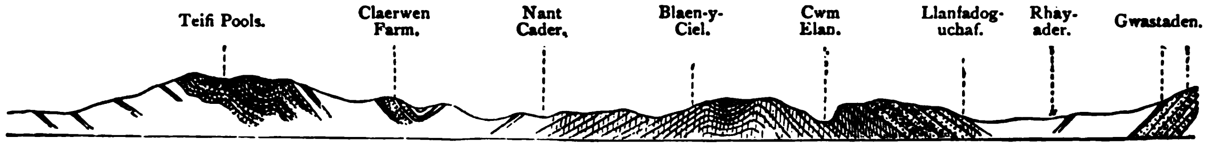
In 1869, Mr. Hopkinson published a list of a few graptolites, which he has discovered at Aberystwith; but, at that time, no great significance was attached to his discovery.

KEEPING'S WORK.

It was not until the year 1881 that any serious attempt was made to unravel the structure of this complex, when Mr. Walter Keeping published a paper on the "Geology of Central Wales." In this paper were embodied the results of three years' field-work over the whole of Central Wales, and in detail within a radius of fifteen miles of the town of Aberystwith. The great value of the author's work lies in the discovery of graptolites in various localities throughout the greater part of the complex. With these fossils as a clue, and with petrological information obtained from traverses throughout the country, Keeping was not only able to prove at last the antiquity of the rocks, but determine to some extent the general structure. One cannot do better than quote the summary at the end of his paper.

"Central and West-Central Wales is made up almost entirely of a great series of imperfect slates and Greywackes belonging to our Cardiganshire group, together with the overlying slates and grits of Rhayader and Plynlimmon. The Cardiganshire group is subdivided into the (1) Aberystwith Grits, and (2) Metalliferous Slates; and part of the underlying slates may, perhaps, hereafter be proved to belong to the same group. Some minor sub-divisions are also distinguishable. The arenaceous rocks are not constant over large areas, but die out to north and south.

The rock-beds are astonishingly folded into violent contortions with frequent inversions, especially in the Metalliferous series, so as often to produce the misleading appearance of a regular and continuous ascending series exceeding five miles in thickness. All the important axes of elevation in the country have a common north and south direction, two of the main folds being the Aberystwith anticlinal and the Plynlimmon synclinal. Secondary



Scale ¼ inch to mile.

FIG. 4.—SECTION FROM STRATA FLORIDA AND TEIFI POOLS TO GWASTADEN.

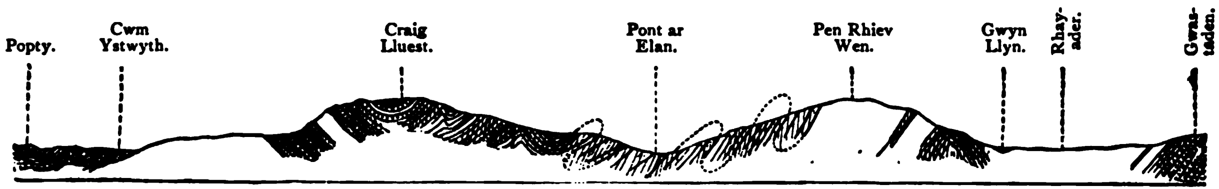


FIG. 5.—SECTION FROM CWM YSTWYTH TO RHAYADER AND GWASTADEN.—*W. Keeping.*

(Approximate length = 18 miles).

axes of upheaval bring up the lower beds of the series at the Devil's Bridge and near Cwm Symlog. Innumerable minor foldings preserve the same north and south strike.

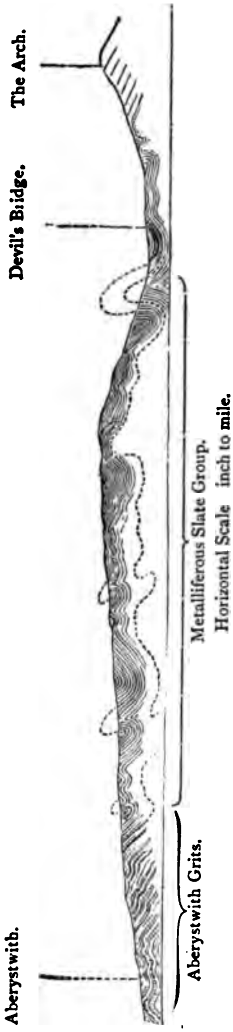


FIG. 6.—SECTION FROM ABERYSTWITH TO DEVIL'S BRIDGE.

The included fossil remains, especially the Graptolites, prove the Aberystwith Grits and Metalliferous Slates to belong to the same general geological horizon, namely, on the parallel of the Upper Birkhill Series of South Scotland (*i.e.*, Upper Llandovery) and the Coniston "Mudstones" of the English Lake District. The Plynlimmon Grits are probably an arenaceous development of the Tarannon Shales, and the Cwm-Elan Conglomerates and Rhayader Pale Slates belong to the same series."

Figures 2 to 6 are sections across Central Wales from Aberystwith to Rhayader, showing the succession and general structure as interpreted by Keeping.

These conclusions will be referred to later in the paper.

GEOLOGY OF THE RHAYADER DISTRICT.

The town of Rhayader lies about ten miles within the south-west border of Central Wales, and about twelve miles north of Builth. The writer devoted the spare time of four years to a detailed study of about twenty square miles around the town of Rhayader, and published the results in 1900.

The following is a summary :

The Rhayader Valley is floored by rocks belonging to three great groups.

(*a*) The Rhayader Pale Shales, equivalent to Lower Tarannon Shales.

(*b*) The Caban Group, equivalent to Upper Llandovery.

(*c*) The Gwastaden Group, equivalent to Lower Llandovery.

The lowest of these—the Gwastaden Group—has a maximum thickness of over 1,800 ft. It is seen completely only at

Rhayader itself lying between the summit of Gwastaden Hill and the town. It is underlain with apparent conformity by a mass of highly-cleaved dark blue shales (Bala), and is overlain unconformably by both the Caban and Rhayader groups.

The base of the Gwastaden series is formed of a thick mass of grits and greywackes (Aa) which thin out eastward and thicken to the west. They contain graptolites of the genus *Climacogruptus* only, and pass up gradually into a series of flags and grits (Ab), which yield only *Climacograptidæ* and *Diplograptidæ.*

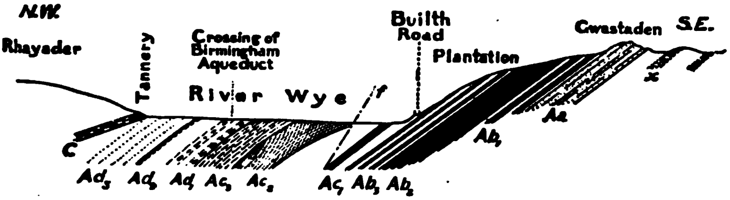


FIG. 7.—SECTION FROM GWASTADEN TO RHAYADER.—*H. Lapworth.*
(Approximate length = 1¼ miles).

C.	RHAYADER PALE SHALES.	*Ac_1.*	Zone of *M. tenuis.*
A.	GWASTADEN GROUP.	*Ab.*	DYFFRYN FLAGS.
Ad.	GIGRIN MUDSTONES.	*Ab_3.*	*D. modestus* Flags.
Ad_3.	Pale Grey Mudstones.	*Ab_2.*	Rottenstone Beds.
Ad_2.	Zone of *M. convolutus*	*Ab_1.*	Micaceous Flags and Grits.
Ad_1.	Calcareous Nodule Beds.	*Aa.*	CERIG GWYNION GRITS.
Ac.	DDÔL SHALES.	*x.*	Blue-black Shales (Bala).
Ac_3.	Zone of *M. fimbriatus.*	*f.*	Fault.
Ac_2.	Zone of *M. cyphus.*		

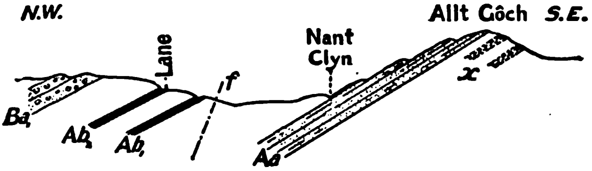


FIG. 8.—SECTION FROM ALLT GÔCH TOWARDS TY'N-Y-GRAIG.—*H. Lapworth.* (Approximate length = ⅞ miles. Lettering as in Fig. 8.)

These are succeeded by a thick group of shales and mudstones (Ac) and (Ad) where the first *Monograptidæ* make their appearance. The variation in the forms of *Monograptus* rapidly increase towards the summit of the group, where this genus becomes predominant.

The Caban Group, which overlies the Gwastaden rocks, has a maximum thickness of 1,500 ft. It is found only in the western areas, between the Rhayader and Gwastaden groups; and is best developed at Caban Côch. Its lowermost division—

the Caban Conglomerates (Ba)—is made up of two massive lenticular conglomerates, with an intermediate set of shales.

The conglomerate group passes up into a set of fine-grained grits, the "*Monograptus Sedgwickii* grits" (Bb_1), and finally into the shales and flags of the Gafallt Shale (Bb_2) division. Each of the various divisions throughout the whole of the Caban Group, when followed eastward from Caban Côch, is found to be overlapped or covered up by the next higher bed, so that eventually the whole of the Caban Group completely disappears beneath the overlying Rhayader Pale Shales (C).

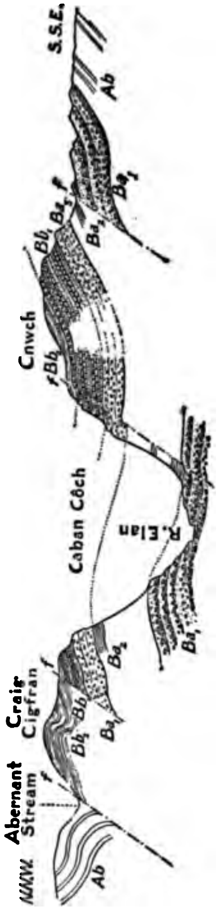


FIG. 9.—SECTION ACROSS CABAN CÔCH, FROM NEAR TY'N-Y-GRAIG TO THE ABERNANT.—*H. Lapworth.* (Approximate length = 1¼ miles.)

Ab.	Dyffryn Flags.
B.	CABAN GROUP.
Bb.	Gafallt Beds.
Bb$_2$.	Gafallt Shales.
Bb$_1$.	*M. sedgwicki* Grits.
Ba.	Caban Conglomerates.
Ba$_3$.	Upper Conglomerate.
Ba$_2$.	Intermediate Shales.
Ba$_1$.	Lower Conglomerate.
ff.	Faults.

The Rhayader Pale Shale Group is made up of pale green, blue and grey shales, and mudstones. It overlaps the Caban

Group, but not necessarily unconformably. East of the point of complete overlap (Cerig Gwynion) these pale shales rest irregularly upon the Gwastaden Group, lying on lower and lower rocks of the group as we pass eastward.

In detail the succession is a follows :

SUCCESSION.	CHARACTERISTIC FOSSILS.
C. RHAYADER PALE SHALES.	*Monograptus exiguus*, *M. crassus*, *M. becki*, *M. crispus*, *M. discus*, worm trails, etc.
B. CABAN GROUP. Average thickness = 1,100 ft.	
Bb. GAFALLT BEDS, 500 ft.	
Bb_2. Gafallt Shales.	*M. lobiferus*, *M. sedgwickii*, worm trails, etc.
Bb_1. *Monograptus-Sedgwickii grits.*	*M. sedgwickii*, *M. clingani*, *M. spiralis*, *Dictyonema delicatulum*, etc.
Ba. CABAN CONGLOMERATES. Max. thickness = 1,000 ft Average thickness = 600 ft.	
Ba_3. Upper Conglomerate.	
Ba_2. Intermediate Shales.	*M. lobiferus* and *Climacograptus normalis.*
Ba_1. Lower Conglomerate.	
A. GWASTADEN GROUP, 1,830 ft.	
Ad. GIGRIN MUDSTONES, 500 ft.	
Ad_3. Pale Grey Mudstones.	*Climacograptus normalis*, *Orthoceras*, etc.
Ad_2. Zone of *Monograptus convolutus.*	*Monograptus convolutus*, *M. lobiferus*, *Diplograptus bellulus*, etc.
Ad_1. Calcareous-Nodule Beds.	*M. leptotheca*, *M. gregarius*, *Rastrites peregrinus*, etc.
Ac. DDÔL SHALES, 600 ft.	
Ac_3. Zone of *Monograptus fimbriatus.*	*M. fimbriatus*, *M. gregarius*, *M. triangulatus*, *Climacograptus rectangularis*, etc.
Ac_2. Zone of *Monograptus cyphus.*	*Monograptus cyphus*, etc.
Ac_1. Zone of *Monograptus tenuis.*	*Monograptus tenuis*, *Climacograptus rectangularis.*
Ab. DYFFRYN FLAGS, 530 ft.	
Ab_3, *Diplograptus-modestus* flags.	*Diplograptus modestus*, *D. longissimus*, *Climacograptus rectangularis.*
Ab_2. Rottenstone Beds.	*Diplograptus modestus*, etc.
Ab_1. Micaceous flags and grits.	*Diplograptus acuminatus*, *Climacograptus normalis.*
Aa. CERIG GWYNION GRITS, 200 ft.	*Climacograptus normalis* and varieties.

Highly-cleaved Blue-black Shales.

Little need be added to the above account. The strike is roughly north-east to south-west. The general dip is from 20°

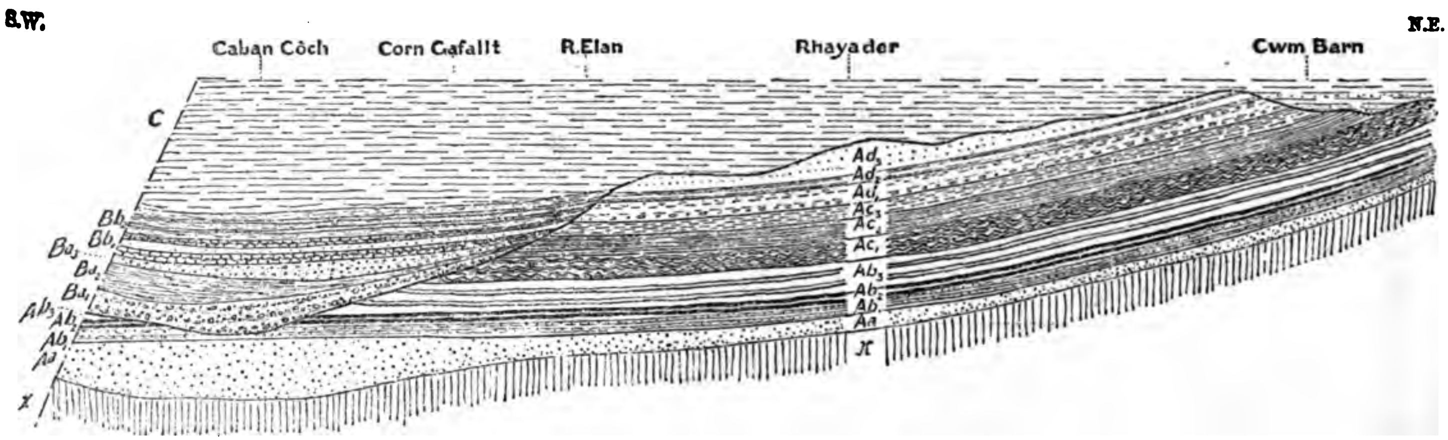


FIG. 10.—DIAGRAMMATIC SECTION FROM CWM BARN TO CABAN CÔCH (Approx. length, 7 miles).—*Herbert Lapworth.*

C. RHAYADER PALE SHALES.

CABAN GROUP.
- *Bb_2*. Gafallt Shales.
- *Bb_1*. *M. sedgwicki* Grits.
- *Ba_3*. Upper Conglomerate.
- *Ba_2*. Intermediate Shales.
- *Ba_1*. Lower Conglomerate.

GWASTADEN GROUP.
- *Ad_3*. Pale Grey Mudstones.
- *Ad_2*. Zone of *M. convolutus.*
- *Ad_1*. Calcareous nodule beds.
- *Ac_3*. Zone of *M. fimbriatus.*
- *Ac_2*. Zone of *M. cyphus.*
- *Ac_1*. Zone of *M. tenuis.*

GWASTADEN GROUP.
- *Ab_3*. *D. modestus* Beds.
- *Ab_2*. Rottenstone Beds.
- *Ab_1*. Micaceous Flags and Grits.
- *Aa*. Cerig Gwynion Grits.

x. Blue-black Shales.

to 30° north-west. The argillaceous rocks are all highly cleaved, the strike of the cleavage being parallel to the strike of the bedding.

There is little folding in the Gwastaden Group, but at Caban Côch crumplings and bucklings in the Caban Conglomerates can be seen from the high road. Faults are common, particularly in the Caban Côch area.

Throughout the Gwastaden and Caban Group graptolites are fairly plentiful, but there are few fossils of any other kind. The Rhayader Pale Shales are practically barren with the exception of the southern fringe. North of Rhayader graptolites are very rare, and are difficult to find, owing to the intense cleavage of the rocks.

Fig. 7 is a section from the top of Gwastaden Hill to Rhayader, and shows the divisions of the Gwastaden (or Lower Llandovery Group) with the overlying Rhayader Pale Shales (or Tarannon Shales).

Fig. 8 is a section about four miles west of the above, showing the relation of the Caban (or Upper Llandovery) to the underlying Gwastaden (or Lower Llandovery) series.

Fig. 9 is a section through Caban Côch at the site of the lowest dam on the Birmingham Water Works, and shows the members of the Caban Group.

Fig. 10 is a diagrammatic section parallel to the strike, and shows the relationships of the three great groups.

FUTURE WORK IN CENTRAL WALES.

It will now be seen on referring back to Keeping's conclusions that the geological structure of the Rhayader portion of Central Wales is nothing like so simple as he imagined it to be; for we have within quite a small area, not only the representatives of his three "Aberystwith" and "Metalliferous" Slate and "Plynlimmon" Groups, *i.e.*, the Upper Llandovery and Tarannon Formations, but in addition the whole of a new formation—the "Gwastaden" or Lower Llandovery, attaining a thickness of at least 1,800 ft.

Now it is this presence of the Lower Llandovery Formation in ground with which he was quite familiar that throws doubt on Keeping's general conclusions as to the geological structure of the Central Wales complex. At the time his paper was written the value of the graptolite as a geological index was not fully realised. The idea was new; and it will be seen from an examination of his monograph that Keeping did not accept entirely the conclusions of Prof. Lapworth (to whom he referred his graptolites for identification), as to the order of the strata. The graptolitic sequence appeared to conflict with the stratigraphical evidence; and, although Keeping apparently recognised that petrological zones could be separated in his "Metalliferous Slate Group," it did not seem to occur to him that this great mass included both the Lower and Upper Llandovery. On page 164 he writes "From the fossil evidence we cannot recognise the Lower part of the Llandovery Group (Lower Birkhill) in Central or West Cardiganshire." On page 167, Professor Lapworth arranged the order of the zones in Central Wales in four groups, and lowest of all—below the Aberystwith Grits—he placed the "*Diplograsus* Beds of Taren-y-Gesail, Corris, and Steddfa Gurig."

It is interesting to note here that with reference to the Corris area, Keeping states on page 153 that the Corris slates are the same as those of Dol-y-Mynach, and the latter have now been proved to be of Lower Llandovery age; while at Steddfa Gurig the writer himself has detected true Gwastaden or Lower Llandovery rocks.

To anyone familiar with the strata of the Rhayader sequence, there is throughout so marked a difference between the Caban and Gwastaden rocks, that it is difficult to imagine the one group being mistaken for the other. The writer has taken only a hasty traverse through Cardiganshire, but was able to detect Lower Llandovery rocks in several places.

It seems, therefore, that the Geology of Central Wales is anything but settled; and that there is still something like 1,800 square miles of "happy hunting ground" left for the amateur geologist. From Keeping's own description of the violent foldings and inversions of the rocks, it is probable that only by patiently zoning small areas in detail, can the geological structure of this vast area be worked out; and, as the author wrote in 1890, "It is not unlikely that the Rhayader Series, in which the sequence is so certain and the graptolite-fauna so definite, will become in time the standard by means of which future geologists will unravel even the tantalising complex of Central Wales."

APPENDIX ON BIRMINGHAM WATERWORKS.

The Elan Valley, which will be visited by the Association on the second day's excursion to the Rhayader District, was secured by the City of Birmingham in the year 1892 for the purpose of augmenting the local water supply, which at that time was rapidly becoming inadequate.

The area of the watershed is about 70 square miles, and is expected to yield a total supply of 70 or 80 million gallons a day.

The ultimate scheme involves the making of six reservoirs; but for the first instalment only three have been constructed, and these only in the valley of the river Elan. The remaining three will be on the river Claerwen.

Four dams have been built already in the Elan Valley, and one on the Claerwen is partially raised. The latter now stands about 30 ft. above the river level, and diverts the water, by means of a tunnel, through the hill into the bottom reservoir, immediately above the submerged dam.

The following are particulars of the reservoirs and dams already constructed :

RESERVOIRS.	Storage capacity in million gallons.	Length in miles.	Area in acres.	Height in ft. above level of sea.
Caban Côch (lowest) .	7,500	4¼	497	820
Pen-y-Gareg . . .	1,300	1¾	124	945
Craig Gôch . . .	2,000	2¼	217	1,040

DAMS.	Height from river to crest.	Length in feet.
Caban Côch (lowest)	120	600
Careg Ddu (submerged)	82	—
Pen-y-Gareg	128	525
Craig Gôch	120	625

The stone for building the dams was obtained chiefly from the Caban Conglomerates from two quarries, one on each side of the river at Caban Côch.

The first work constructed was a railway from Rhayader to Caban Côch for the transport of materials. This railway was eventually extended to the highest dam, for the purpose of conveying stone and materials for the building of the dams. Concurrently a village for navvies was erected immediately below Caban Côch.

The aqueduct to Birmingham, which is about eighty miles in length, commences at the submerged dam with a tunnel through Craig-y-Foel to a site immediately below Caban Dam, where the water is roughly filtered.

The submersion of the existing roads by the reservoirs has necessitated the construction of new roads above the highest top water level in each reservoir. One of these extends from Caban Côch Dam to Pont-ar-Elan, about eight miles in length, running alongside the Caban Côch, Pen-y-Gareg and Craig Gôch Reservoirs. This will form part of the drive on the visit of the Geologists' Association to the Elan Valley.

The scheme was commenced in 1892, and the opening ceremony was performed by the King in July, 1904. At that date the Caban Côch, Pen-y-Gareg, and Craig Gôch Reservoirs were practically completed. This Welsh water, therefore, has now been used in Birmingham for a period of twelve months.

The engineer for the scheme was the late Mr. James Mansergh, Past Pres. Inst.C.E., and the resident engineer in the Elan Valley is Mr. G. N. Yourdi, M.I.C.E.

For the use of the figures illustrating this paper we are indebted to the Council of the Geological Society.

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ON THE IGNEOUS ROCKS OF THE WELSH BORDER.

With special reference to the Long Excursion for 1905.

BY PROFESSOR W. W. WATTS, M.A., F.R.S., SEC. G.S.

(Read July 7th, 1905.)

I. INTRODUCTION.

IN studying the igneous rocks of any extensive area in the attempt to elucidate its volcanic history there are three great principles to be borne in mind.

1. That there is usually a time relation between earth-movement and vulcanicity.

2. That the location of the vulcanicity is definitely related to the direction and intensity of the movement.

3. That there is a tendency for earth-movements to recur at the same place, and often in the same sense, in different geological periods, and that, therefore, there will be a corresponding tendency towards the local recurrence of igneous phenomena.

1. The four great periods of earth-movement in Britain which have left their marks in Wales are the Post-Archæan, the Post-Ordovician, the Post-Carboniferous, and the Post-Eocene. Three of these periods, if not the fourth, have been accompanied by volcanic action. With the first are associated the Longmyndian and Uriconian volcanic rocks, with the second the great outburst of volcanoes during the Ordovician Period, and with one or both of the last two periods possibly certain rocks in Pembrokeshire and others which project a short distance into Wales from the eastern border.

2. In the classic instance of the Bala volcanic rocks, Mr. Harker* has demonstrated that the Snowdonian vulcanicity was ruled by the existence of resisting "breakwaters" such as that of Llanberis, against which the earth-wave broke, producing a line of vents running from Penmaenmawr, through Foel Fras, to Mynydd Mawr and perhaps beyond. I believe that a corresponding though less evident association can be traced in connexion with the great anticlinal masses out of which the structure of Wales is built up. These masses run on the whole N.E. to S.W., and may be grouped as follows: (*a*) The Llanberis anticlinorium; (*b*) the Harlech anticlinorium; (*c*) the Berwyn anticlinorium; (*d*) the Longmynd-Builth anticlinorium; (*e*) the anticlinorium of the Malvern fracture-line; and lastly (*f*) the St. David's anticlinorium.

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* "The Bala Volcanic Series of Caernarvonshire," Cambridge, 1889.

The word anticlinorium is used in preference to the simpler term anticline, because the structure of each of these areas is complex, as is well known, and in particular because there are often smaller associated synclines such as that of Menai, usually devoid of igneous rock. There are also smaller attached anticlines like that of Old Radnor and the Wrekin. Moreover, there are associated faults such as those of Bala, Berwyn, Breidden, and the Lilleshall-Caradoc-Radnor fault.

3. Whatever may have been the primary origin of these anticlinoria, three things are quite certain;—that they are very ancient; that they have been persistent throughout geological time, indeed they might also be called pertinacious; and they have been again and again associated with volcanic action. Shropshire furnishes an example which is typical of the other areas. Without entering into the vexed question of the relations of the Longmyndian and Uriconian Rocks we are sure that these rocks were being denuded in shallow water to furnish the basal beds of the Cambrian; so the Longmynd area was brought into the reach of denudation, for the first time within our knowledge, by Cambrian or Pre-Cambrian movement. The unconformity of the Bala beds on Uriconian and Cambrian Rocks on the east side of the Longmynd proves that N.E. to S.W. movement was going on in Ordovician times, just as has been shown by Harker in Caernarvonshire. Nowhere has this movement, recurring in Post-Ordovician times, produced more marked effects than in the Silurian unconformity of Shropshire. And there is plenty of evidence of movement, land, and denudation, in Carboniferous, Permian, and Triassic times. Later than this we are without evidence.

Three of these periods of activity at least were accompanied by vulcanicity of a complicated character, and extending throughout a long geological interval, and in most of the anticlinoria not less than two, and sometimes all three, volcanic episodes are represented. Although in each area the volcanoes of a particular period had a definite local sphere of activity, their products are not by any means confined to such spheres, but encroach on those of previous episodes. This has given rise to a series of difficulties in the geology of Wales, hardly less serious than those resulting in the stratified rocks from the complicated geological structure of the ground. Many of the mistakes already detected in the interpretation of the geology of Wales have come from ignorance of this fact, and the recognition of it in differen[illegible] regions by Ramsay, Hicks, Bonney, Callaway, Harker, Lapworth and others, marks the successive stages in the right knowledge [illegible] the country. Even yet many difficulties remain in the mo[illegible] complicated districts, for, unlike the sedimentary rocks, no dat[illegible] stamp appears to have been used in the manufacture of igneo[illegible] rocks.

II. THE LLANBERIS ANTICLINORIUM.

It will be sufficient to refer the reader to Mr. Harker's* Memoir on "The Bala Volcanic Rocks of Caernarvonshire" for a complete description of the phenomena of this tract. Two masses of Archean igneous rock occur here, one stretching S.W. from Bangor, and a second running N.E.-S.W. through Llyn Padarn. The rocks are mainly felsites and quartz-porphyries associated at Caernarvon with granitic rock. The eastern mass is flanked by the Snowdonian (Bala) tuffs and lavas, mainly of acid composition, extending between Conway and the Lleyn. Large intrusive masses of plug-like type run parallel and to the N.W. of the Snowdon range, and there are numerous intrusive acid and intermediate rocks such as granites, syenites, and granophyres. There are also more basic intrusions ranging from andesites to dolerites, gabbros, and picrites, which are Post-Ordovician and probably Post-Silurian in age. Younger intrusive dykes, probably Post-Carboniferous, if not later, are found in Anglesey.

III. THE HARLECH ANTICLINORIUM.

The mass of sedimentary Cambrian rock in the core of this anticline is penetrated by numerous dykes and sills of igneous rock. It is flanked by the products of a great series of volcanoes, entirely from the Moelwyns and Manods, through Arenig and Aran, to Cader Idris. These eruptions,† according to Cole, began in Tremadoc times, but were most active in Arenig or Llandeilo time. As usual there are approximately contemporaneous plutonic intrusions, such as the granite of Tan-y-Grisiau, and later intrusive sills and laccolites of basic material, usually dolerites and gabbros devoid of olivine. The volcanoes of the period appear to have been situated around the anticline, and not to have encroached upon the core to any great extent. Later igneous rocks have not been detected for certain in the area, and even the Bala rocks are non-volcanic here.

IV. THE BERWYN ANTICLINORIUM.

A. THE BERWYNS.

The most recent notice of the igneous rocks of this area is that by Messrs. Cope and Lomas, which appears in abstract in the Annual Report of the British Association for 1903. The rocks occur as an incomplete dome showing, according to the Geological Survey Map, tuffs and intrusions in the middle,

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* Vol. *cit.*

† *Geol. Mag.*, Dec. 3, vol. iii, 1886, p. 219.

probably of Arenig or Llandeilo age, and round the outer edge other tuffs, of Bala age, also associated with intrusive rocks. Messrs. Cope and Lomas, however, have failed to find any evidence of contemporaneous volcanic activity. They regard the rocks as intrusive, with fragments of sediments caught up in them, or else with flow-brecciation; the rocks have also been much crushed. The rock-types are diabases, rhyolites sometimes nodular, and perhaps rocks of intermediate composition. They present many resemblances to those described by Hatch and others in Wicklow and Wexford. The authors conclude that the intrusions are pre-Wenlock.

B. THE BREIDDENS.

This little district forms a bridge between the Berwyn area and that of Shelve. It is almost certainly bounded by a large fault on the west along the line occupied by the Severn Valley, as instead of the Llandeilo or Arenig rocks, which should occur to the west, Silurian rocks are found there. Contemporaneous tuffs and agglomerates are interbedded with Bala beds, these fragmental rocks yielding fossil evidence of submarine origin. There are also interbedded andesitic lavas closely related to those of the Stapeley and Todleth Ridge in the Shelve country. Piercing the other rocks there are hypersthene-diabases certainly Post-Bala in date and almost certainly Post-Llandovery. These occur as sills and laccolites, the fine crags of Rodney's Pillar Hill being the best example of the former.

Mr. Jevons,* finding the felspar in two specimens of the "andesites" of Moel-y-Golfa to be albite, determines these rocks as keratophyres, and he extends the same conclusion to those sills of the Berwyn area which have been called diabases. He also hazards the conjecture that the intrusive rocks called diabases by the writer in the Breiddens may belong to the keratophyre group. If correct these determinations will do something to unify the types of Ordovician and Post-Ordovician rocks of different areas, since keratophyres undoubtedly exist in the Wicklow and Wexford areas, in the Pembrokeshire district, and, as Rosenbusch indicates, will undoubtedly be found in Snowdonia and possibly in the Arans and Arenigs.

V. THE LONGMYND-BUILTH ANTICLINORIUM.

1. THE POST-ARCHÆAN ROCKS.

These rocks are distributed at intervals round the Longmynd, from Lilleshall, through the Wrekin and Caradoc, to Warthill Knowl on the east, and from Pontesford Hill to Knolls Wood on

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* *Geol. Mag.*, Dec. v, vol. i, 1904, p. 13.

the west. They consist of rhyolites in the main, interspersed with andesites and more basic rocks. Many descriptions of portions of these rocks have been given by various writers, but the only one which combines the result of detailed field-mapping with petrographical work is the account of Pontesford Hill, by Professor Boulton.* For our present purpose that area may be selected as a type. Even here it was not always possible to discriminate between interbedded and intrusive rocks, but the former seem to include not only rhyolites, but andesitic rock of varying degrees of acidity, together with acid and intermediate tuffs and palagonite tuffs. Intrusive into this series are olivine-dolerites, which Boulton likens to those associated with Carboniferous rocks in many border localities. More or less similar rocks and associations are found in other masses such as the Wrekin and Caer Caradoc. Numerous intrusive rocks have been noted in the Longmynd country, and described by Mr. Cobbold,† in part from microscopic descriptions of the writer. Many of these are olivine-dolerites of the type just mentioned, but there is one type worthy of special note, a hornblende-diorite or camptonite related to those of Nuneaton. This rock-type has also been found in contact with Uriconian rocks at the Lickey, and with Cambrian quartzites and shales at the Wrekin and Malvern, but never with anything more recent, so that it probably represents the last phase of Post-Archæan activity. Neither lavas nor tuffs are known in this area amongst Cambrian rocks, and this period appears to have been one of tranquillity.

2. ORDOVICIAN AND POST-ORDOVICIAN ROCKS.

A. THE SHELVE AREA.

As is the case in North Wales the vulcanicity broke out during two maxima, one in the Arenig and the other in the Bala Period, the intervening Llandeilo Period showing evidence of merely local and sporadic outbursts. The rocks are almost exclusively andesites in the form of lavas and tuffs, with some intercalations of trachytic rocks and a few breccias made up of rhyolite fragments. The lower volcanic band occurs just below the zone of *Didymograptus Murchisoni*, and the higher one well up above the base of the Bala. The tuffs are fossiliferous in both cases and were deposited under marine conditions. The last stages of vulcanicity were marked by the intrusion of sills, laccolites, and dykes, along surfaces of movement due to folding, faulting, and torsion. The earlier of these are hypersthene—and

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* *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 450.

† Caradoc and Severn Valley Field Club, "Record of Bare Facts," 1894-1896, *vide* also Church Stretton, Shrewsbury.

augite-diabases similar to those of Snowdonia; these have been found in contact with Silurian Rocks and are hence Post-Silurian in date. The later are more basic and pass into augite-picrites, but it has not been possible to ascertain their age. Most of the associated sediments such as the Lower Arenig flags and the basal Llandeilo grits are mainly made up of volcanic débris, and sometimes contain bands of china-stone ash, and genuine tuff.

B. THE CARADOC AREA.

In this area there are no known Arenig or Llandeilo rocks, and the base of the Bala rocks rests unconformably on older strata; hence this area was land during earlier Ordovician time. But, as at Pontesford, there are basic rocks intrusive among the Uriconian rocks which are of unknown age. Many of the Caradoc Sandstones are made of volcanic material which cannot have travelled far from a volcano, and the more ashy beds are proved by their fossils to be contemporaneous with the Bala ashes of the Shelve District on the west side of the Longmynd.

C. THE BUILTH AREA.

The igneous rocks of the southern part of this district were described by Mr. Woods* in 1894, and that author found that they were related in character to those of the Shelve region. There are andesitic ashes which appear to be at the top of the Arenig strata, underlying beds containing Llandeilo fossils; andesites closely related in composition to the ashes, but apparently intrusive into them; rhyolites and rhyolitic ashes; and intrusive masses of diabase-porphyrite and of diabase. It does not appear that the andesites, though intrusive, are very far separated in point of age from the ashes of similar composition, a relationship which seems to prevail in Shropshire and at Arenig itself. No Bala rocks were found by Mr. Woods. The diabases are thought by Mr. Woods to be Post-Llandeilo and Pre-Silurian in age.

Farther to the south-east igneous rocks were discovered by Murchison, and mapped by the Geological Survey; one group near Llanwrtyd, about ten miles W.S.W. of the Builth area; a second near Llangadock, half way between Llandeilo and Llandovery; and a third group about six miles S.W. of Caermarthen. Of these areas no recent descriptions have been published.

3. OTHER IGNEOUS ROCKS.

A very remarkable group of igneous rocks about which there is much difference of opinion was visited by the Association in 1904 near Kington and Old Radnor. These rocks were briefly

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* *Quart. Jouru. Geol. Soc.*, vol. l, 1894, p. 566.

noted by Callaway[*] in 1879, and afterwards described in outline by Professor Cole[†] and Mr. F. Raw.[‡] Dr. Callaway[§] subsequently claimed the hard greywackes of Old Radnor as Longmyndian in age, and showed that they were unconformably covered by sediment partly belonging to the Llandovery epoch. Associated with them there are acid and basic rocks of uncertain age, the former being felsites and granophyres, and the latter "augite-diorites," diabases, and gabbros. This group of rocks was referred by Dr. Callaway with hesitation to the Pre-Cambrian Period, but it is interesting to note that both Murchison and Cole in describing the rocks find the majority of their comparisons in Skye. This and other evidence, though far from conclusive and indeed rather of the nature of suggestion than proof, makes it desirable to consider the possibility that these rocks may belong to the Tertiary group.

There is in the Midlands a group of olivine-dolerites of which it is difficult, if not impossible, to ascertain the age. They are generally intrusive into the Coal-measures, and thus cannot well be earlier than Permian. But they are altogether different from such known Permian igneous rocks as those of Devon and South Scotland. If they should belong to the Mesozoic Period they would be unique in Britain, for this was an era of remarkable tranquillity both in respect of organic movement and vulcanism. Moreover, certain undistinguishable rocks occur in the Leicestershire coal-field intrusive between Coal-measures and Trias, and at Butterton and Swinnerton, in Staffordshire, actually intrusive into Permian and Triassic Rocks. In seeking for evidence of age for one of the chief of these dolerites, that of Rowley Regis, Jukes found that while intrusive into Coal-measures this rock was disturbed by the latest earth movement that had been felt in that area. Such movement may well be Tertiary in date, as it cuts into the neighbouring Jurassic Rocks and is parallel to faults and folds which traverse more distant Cretaceous and Eocene Rocks. Further, Allport, in examining the petrology of these rocks could find no points of difference between them and the known Tertiary dolerites of Antrim and the Inner Hebrides.

Again similar rocks are not infrequently associated with very ancient rocks in the Isle of Man and Ireland, and may be traced from thence into the neighbourhood of the Tertiary rocks of Scotland and Antrim. It has been more than once suggested by the writer that in default of evidence to the contrary it may be well to keep in view the possibility that this group of olivine-dolerites may be of Tertiary age. Now if a line be drawn from the southern part of the Leicestershire Coalfield to Rowley and Wednesbury, it will pass through the similar rocks of Kinlet and

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[*] *Quart. Journ. Geol. Soc*, vol. xxxv, 1879, p. 643.
[†] *Geol. Mag.*, Dec. iii, vol. iii, 1886, p. 219.
[‡] *Proc. Geol. Assoc.*, vol. xvii, 1904.
[§] *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 511.

the Clee Hills, and if produced it will cut into the Old Radnor area. That is to say, a group of olivine-dolerites undistinguishable from the Tertiary lavas and intrusive rocks of Skye or Antrim falls into line with a group of rocks closely comparable with the intrusive bosses and laccolites of Skye or Barnavave or Carlingford. An almost parallel band would include the Butterton dyke, the olivine-dolerites of Little Wenlock and the Wrekin, and the similar rocks which have been mentioned as intrusive into the Archæan rocks of Caradoc and the Longmynd. Such a line would run parallel with that drawn by Harker in his recent Memoir to limit the extension of Tertiary volcanic rocks according to present knowledge. It would lengthen the radius of this area by forty miles. Thus a broad belt may exist along which Tertiary vulcanicity endeavoured to assert itself wherever weak places existed as manifested by the protrusion of ancient rocks along the belt. If this course of argument is permissible it may be that many of the later intrusive rocks associated so frequently with Archæan rocks in Midland England and Wales may be of Tertiary age.*

VI. THE MALVERN ANTICLINORIUM.

The only igneous rocks exposed along this important line are those about Malvern and at Tortworth, the former belonging mainly to the Post-Archæan and the latter to the Post-Ordovician type. Tracing the anticline from north to south the basal rocks along the line are Silurian at Abberley and Tortworth, crystalline Archæan at Malvern, and Longmyndian (according to Dr. Callaway) at May Hill.

A. THE MALVERNS.

The core of the Malvern Hills consists of a highly complex plutonic and gneissose series into which doubtless many later rocks have been intruded. Callaway, Green, Rutley, Acland, and Groom have described the rhyolitic tuffs, andesites and basalts, of Herefordshire Beacon, which seem to be similar to the typical Uriconian rocks. No later contemporaneous volcanic rocks have been discovered and the Ordovician rocks seem to be absent from the region. Intrusive into the Cambrian rocks, however, are numerous sills and dykes of several rock-types, including camptonites of the Nuneaton character ("amphibole-bearing rocks of andesitic habit")† augite-basalt, olivine-basalt, and olivine-diabase. Groom thinks it likely that these rocks are Pre-Silurian but it appears possible that while certain of the rocks are of this date some of the series, as elsewhere, may be younger.

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* "The Tertiary Igneous Rocks of Skye," *Mem. Geol. Survey*, 1904, p. 3.

† *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 156.

B. TORTWORTH.

Our latest account of the rocks of this district is by Professors Lloyd Morgan and Reynolds.[*] They find that tuffs occur on two horizons, one group covered by strata of Upper Llandovery age, and the other by beds of Lower Wenlock age. Associated with these are highly decomposed and amygdaloidal lavas generally about intermediate in composition, and classed either as pyroxene-andesites or as basalts. Part of the pyroxene in these rocks is rhombic, thus furnishing a link with the Post-Silurian intrusions of Shropshire and elsewhere. This rock group is of remarkable interest as it presents the only example of effusive rocks of Silurian age in Great Britain.

VII. THE ST. DAVID'S ANTICLINORIUM.

A very brief note and reference to authorities in this area must suffice for our present purpose. Hicks, Teall, Rutley, Reed, Parkinson, Elsden, Howard, and Small have all dealt with portions of the region.

A. THE ST. DAVID'S AREA.

The Archæan complex includes granitic rocks, rhyolites, and intrusive basic rocks. The north-easterly prolongation of the anticline is flanked by bedded and volcanic rocks belonging to two horizons in the Ordovician, the lower associated with the zone of *Didymograptus Murchisoni*, and the higher classed by Mr. Reed[†] with the Upper Llandeilo and Lower Bala. These rocks seem to be chiefly felsites and rhyolites, often nodular and spherulitic. The intrusive rocks cover a wide range in composition, and have recently been considered in detail by Mr. Elsden.[‡] The oldest of the intrusions are lime-bostonites, which are more basic than the keratophyres of south-eastern Ireland, but seem to be related to them. These were followed by gabbros and norites, and these again by the intrusion of the great basalt laccolite of Pen-Caer. Amongst the intrusions Mr. Cowper Reed found variolitic rocks. There appears to be no precise evidence of the age of the intrusive rocks.

B. THE SKOMER AND MILFORD AREAS.

Work has been done recently in this area by Messrs. Howard and Small.[§] They find interbedded rhyolites and basalts, and

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[*] Ibid, p. 267.

[†] *Quart. Journ. Geol. Soc.*, vol. li, 1895, p. 149.

[‡] *Abstract Proc. Geol. Soc.*, 1904, p. 95.

[§] *Annual Rep. Brit. Assoc.* for 1896, p. 797. *Trans. Cardiff Nat. Soc.*, vol. xxviii, 1896, and vol. xxix, 1897.

plutonic rocks such as granites and quartz-diorites. They seem to be unable to find any precise date to the vulcanicity, and there exists a bare possibility that the rocks may be due to the Post-Carboniferous movement.

CONCLUSIONS.

On reviewing the igneous rocks of Wales and its border counties and countries there are a few conclusions which have forced themselves on the writer.

1. The Irish Sea is girt with a belt of igneous rock of various ages, the ring being more complete in Wales and south-east Ireland than elsewhere. Here, indeed, a buckling of the ring is produced by the projection of the Lleyn towards Wicklow and the southern basin of the Irish Sea is thus defined. This part of the ring, however, not only encloses this basin but all Central Wales as well, which is devoid of any igneous rocks whatever.

2. In Wales itself the igneous phenomena are generally associated with the principal anticlinoria, of which six have been considered in more or less detail.

3. As a general rule the volcanoes were situated round the edge of the anticlines, where such roots as have been discovered are mainly situated. Doubtless the lavas and tuffs originally spread to some extent over the cores of the anticlines, from which they have been removed by denudation, but the scarcity or smallness of the later intrusive rocks inside the anticlinal areas seems to show that the volcanoes themselves were marginal; they are a phenomenon of the "middle limb." The Berwyns appear to present an exception to this rule, but in this case the anticline may be of later date than the others, and the type of vulcanicity is exceptional.

4. Most of the anticlinoria have again and again been the foci of the vulcanicity of successive periods, but there is a decided tendency for them to progressively migrate towards the exterior.

5. The Post-Carboniferous vulcanicity does not appear to have anywhere penetrated far into Wales, possibly because the movement was not sufficiently "strenuous" to affect the already moved ancient rocks of the region. The most probable exception is that given by the rocks of Skomer and Milford, where we come within the scope of the greater power of the Armorican movement. With the exception of South Scotland, the volcanic action of this period does not appear to have had great power, and the igneous rocks of Devon and Derby give evidence of only very feeble action.

6. The tremendous earth-movement and volcanic outburst of Tertiary times developed on such a gigantic scale on the flanks of the northern prolongation of the Irish Sea, and of the northern


-REFERENCE-
C
RHAYADER PALE SHALES.
Bb
GAFALLT BEDS.
2
Gafallt Shales.
1
M-Sedgwickii Grits.
Ba
CABAN CONGLOMERATES.
3
Upper Conglomerate.
2
Intermediate Shales.
1
Lower Conglomerate.
Ad
GIGRIN MUDSTONES.
3
Pale Grey Mudstones.
2
Zone of Monograptus convolutus.
1
Calcareous Nodule Beds.
Ac
DOLL SHALES.
3
Zone of Monograptus fimbriatus.
2
Zone of Monograptus cyphus.
1
Zone of Monograptus tenuis.
Ab
DYFFRYN FLAGS.
3
Diplograptus modestus Flags.
2
Rottenstone Beds.
1
Micaceous Flags and Grits
Aa
CERIG GWYNION GRITS.
CLEAVED DARK SHALES.
CABAN GROUP
GWASTADEN GROUP
Venrhy
Fawr
on
Careg
Ce
Llanfa
q.
NGHA
Wood
d.
Llwyn-y-baedd.
Chwch
Cwm Barn.
River Dulas
Cla
Roun
raig
Cwm-glas-cwm.
Lan Goch
Erw-daigae.
Pe.
rubley.
ive
Great Vaynor.
Little Vaynor.
och
Little Castle.
Ty-isaf.
reat Castle.
New Inn.
H. Lapworth. 1899.

basin of the sea itself, succeeded in forcing its way inwards, and thus we find what are almost certainly Tertiary igneous rocks not only on the borders but inserting themselves right into the heart of the older igneous masses.

7. It is this "ring-fence" of volcanoes, and the mountain masses which have resulted from them, which have been responsible for preserving the individuality of the country. If the rivers which come from within had not themselves breached this single, double, or even triple rampart, Wales would have held the invader outside her fastness even longer, though certainly not more bravely, than she did.

NOTE ON SOME PORTIONS OF MOSASAURIAN JAWS OBTAINED BY MR. G. E. DIBLEY FROM THE MIDDLE CHALK OF CUXTON, KENT.

By A. SMITH WOODWARD, LL.D., F.R.S.

[*Read June 2nd, 1905.*]

MOSASAURIAN remains are so rare in the English Chalk, that two associated fragments of jaws recently obtained by Mr. Dibley from the zone of *Holaster planus* at Cuxton, Kent, are worthy of brief notice. They seem to represent a known species, but exhibit some new features of the jaws to which they belong.

The specimens comprise the middle portion of the right maxilla exposed from its outer face (Fig. 1), and a piece of the hinder half of the right mandibular ramus free from matrix (Fig. 2). The maxilla deepens very rapidly behind, where its sharp upper border bends upwards; while so far as can be judged from the broken end of the fossil, the same bone must have been quite slender and tapering in front. Its outer face is gently convex and nearly smooth, with the usual row of nutritive foramina. The portion preserved has sockets for six teeth, of which only three remain; but these are shown to be of the typical Mosasaurian pattern. The crown of each tooth is stout and recurved, with the inner face almost as convex as the outer face, while the blunt anterior and posterior keels seem to be confined to the apical half. The enamel is nearly smooth, with slight traces of delicate longitudinal striæ and transverse growth-lines, but no flattened facettes. The fragment of mandible (Fig. 2) proves the ramus to have been slender, with the coronoid not much elevated. The coronoid bone itself is lost, but the

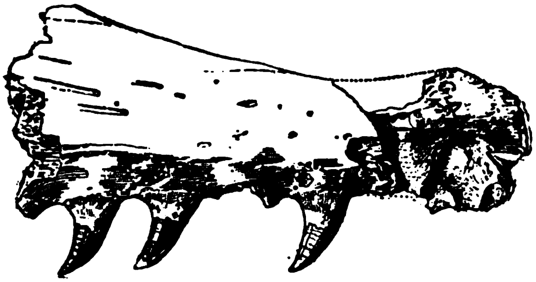

FIG. 1.—*Mosasaurus gracilis*, OWEN; PORTION OF RIGHT MAXILLA, OUTER ASPECT, TWO-THIRDS NATURAL SIZE.—ZONE OF *Holaster planus;* CUXTON, KENT.

inner side of the fossil shows the facette on the surangular for its accommodation (*co.*). The long and low surangular (*s.ag.*) has the usual sinuous upper border. The thick articular bone (*ar.*) is broken behind, but it clearly extends forwards in the ordinary manner as a long splint on the inner face of the jaw. The long and slender angular bone (*ag.*) completes the specimen below.

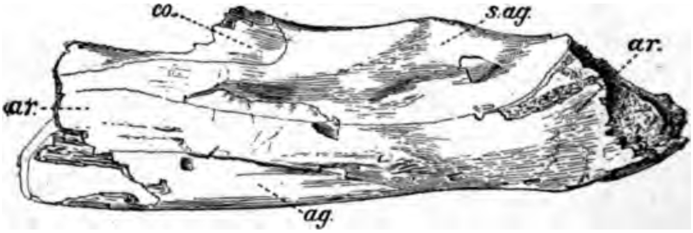

FIG. 2.—*Mosasaurus gracilis*, OWEN; HINDER PORTION OF RIGHT MANDIBULAR RAMUS, INNER ASPECT, TWO-THIRDS NATURAL SIZE.—ZONE OF *Holaster planus;* CUXTON, KENT.

ag., angular; *ar.*, articular; *co.*, facettes for coronoid; *s.ag.*, surangular.

Fragments such as these obviously do not admit of exact generic determination, but, as may be inferred from the description, there is no reason why they should not be assigned to the genus *Mosasaurus* itself. Moreover, they agree in size and in dental characters with the jaws of *Mosasaurus gracilis* described by Owen* from the Chalk of Offham, Sussex, which seems to be partly on the same horizon as that of Cuxton from which Mr. Dibley obtained the new specimens. They may therefore be regarded as belonging to the species just mentioned, and as making known for the first time the middle part of its maxilla and the hinder half of its mandible.

The jaws named *Mosasaurus gracilis* were regarded by O. C. Marsh and W. Davies as not being Mosasaurian, but referable to the predaceous fish, *Pachyrhizodus*; and I was for some time of the same opinion.† I am now convinced, however, that Owen was correct in his interpretation of the original specimen, which is now in the Brighton Museum. It differs from the jaw of *Pachyrhizodus* not only in the texture of the bone, but also in the penetration of the dentary element by a longitudinal canal, which is filled with chalk and well exposed in a fracture near the symphysis.‡ The Mosasaurian nature of the new specimens is shown both by the firm—not flaky—texture of the bone, and also by the characteristic arrangement of the hinder elements of the mandible.

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* R. Owen, "Monogr. Rept. Cret. Form." (*Palæont. Soc.*, 1851), p. 31, pl. ix, fig. 1; pl. ixA, fig. 9. Also in Dixon's "Geol. Sussex," p. 380, pl. xxxvii, fig. 1.

† A. S. Woodward, "Synops. Vert. Foss. English Chalk," *Proc. Geol. Assoc.*, vol. x (1888), p. 314.

‡ See Owen's pl. ix, fig. 1, *d*, *op. cit.*, 1851.

It may be added that Mr. Dibley has also recently discovered ortions of small Mosasaurian vertebræ in the upper part of the one of *Holaster subglobosus* at Wouldham, near Rochester. This seems to be the lowest horizon in the European Chalk rom which Mosasaurian remains have hitherto been obtained.

ORDINARY MEETING.

FRIDAY, MAY 5TH, 1905.

SMITH WOODWARD, LL.D., F.R.S, President, in the Chair.

The following were elected members of the Association: obert H. Hamilton, H. F. Jones, Charles Thomas Palmer, iss Amy P. Pearse.

A lecture was then delivered by Dr. W. J. Holland, Director f the Carnegie Museum, Pittsburgh, entitled "Explorations r Fossil Bones in Western North America," with special eference to the skeleton of *Diplodocus*, of which a plaster cast s now being mounted in the British Museum (Natural History). The lecture was illustrated by lantern slides.

ORDINARY MEETING.

FRIDAY, JUNE 2ND, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

A paper was read by Mr. G. W. Young on "The Chalk Area f North-East Surrey," the paper being illustrated by numerous pecimens and diagrams.

ORDINARY MEETING.

FRIDAY, JULY 7TH, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: Thomas G. Lees, J. H. Milton, Miss Ethel Mary Reader Wood.

Mr. J. L. Foucar exhibited a specimen of *Phyllodus* from he Blackheath Beds, S.E. of Well Hall, Kent, and the Secretary xhibited, on behalf of Mr. J. Chambers, a photograph of some lint implements found at Lowestoft.

The following papers were then read: "The Geology of Central Wales," by Herbert Lapworth, F.G.S., and "The Igneous Rocks of the Welsh Border," by Prof. W. W. Watts, M.A., F.R.S.

THE CHALK AREA OF NORTH-EAST SURREY.

By GEORGE WILLIAM YOUNG.

(Read June 2nd, 1905.)

ALTHOUGH one might consider that the last word not been said about the Chalk formation as a whole it might be fairly thought that if there was an area in the cou which had been thoroughly explored and its structure accur recorded, that area would be the Chalk of North-East Surrey

But notwithstanding its nearness to London, the numbe observers who have given their attention, and the frequency which some of the best-known sections have been visited by and other scientific societies, I venture to think that the fac am about to lay before you will show that even in this area t is still work to be done.

When the first of the valuable series of papers on the W Chalk by Dr. Rowe appeared in our PROCEEDINGS my interest aroused, and I looked forward with considerable anticipatio the publication of the last Volume of the Geological Su Memoir on the Cretaceous formation, which was to deal with Upper Chalk. With this volume I must confess I was somew disappointed. I fully admit that in many respects it is admirable work. The labour entailed in its compilation r have been enormous. The wide area with which it deals; valuable and detailed account of the microscopic structur Chalk; the useful information and statistics it gives about economic products and water supply; the exhaustive list of fo and the bibliography given in the appendices; all testify to great pains that have been bestowed upon it.

Yet when one turns to the chapter upon Surrey one ca fail to be struck with the brevity of the description. This is admitted by Mr. Jukes-Browne himself, for he opens the cha with the following paragraph: "No systematic exploration of Upper Chalk of Surrey has yet been made, notwithstandin proximity to the Metropolis, and the frequency of exposure quarries and railway cuttings." He then refers to the known papers of Mr. Caleb Evans and Mr. Dibley, both valu contributions, the former especially so, as Mr. Evans had the op tunity of examining a nearly complete section of the beds to w access is now impossible. It also shows that he, though writir 1870, before Prof. Barrois had published his classic work, fully grasped the importance of the zonal system of classifica

Soon after the publication of this memoir the discover *Marsupites testudinarius* in this area led me to a more ca examination of the district, and eventually to attempt a thor and systematic zonal exploration so far as the limited time at disposal would allow.

Taking the Ordnance Survey Map of 6 ins. to the mile as a basis, I noted every quarry and chalk pit marked, giving each a distinctive number. In this small area of about 100 sq. miles there are no less than 235 pits, of which I have visited 179 up to the present time. Many of these, of course, are no longer in use, some are completely overgrown with either turf or brushwood, while in others large trees, including such slow growers as the yew, show how long they have been abandoned. In 93 instances, however, I have found sufficient exposure and sufficient fossils to enable one to refer the chalk in the pits with considerable confidence to its proper zone.

The distribution of the pits is peculiar and of great interest. They are not scattered at random, but are much more numerous in certain localities, while in other large areas scarcely a pit can be found. They tend to occur in linear series which often coincide with contours of altitude, in some cases remarkably so; for instance, on the two adjacent sheets of Chipstead and Coulsdon there are 48 pits, 35 of which are within 20 ft. of the 500-ft. contour line.

Now a few words as to the mass of the Chalk before we consider the pits in detail. The area I have taken extends from Addington to Oxted on the East, to the gorge of the River Mole on the West. It is of course bounded by the Tertiary beds on the North and the Upper Greensand on the South.

The outcrop is about 7 miles wide on the East but rather less than 4 miles on the West.

We have here to do with the Northern limb of the Wealden anticline, but the dip is extremely low in the broader part of the area. For instance, the base of the Chalk at the Streatham boring is 819 ft. below O.D., while at White Hill, 11 miles south, it is 470 ft. above, a rise of 1,289 ft. in the 11 miles, which works out at an average dip of less than 1⅓ deg., or 117 ft. per mile. The slope, however, varies in degree. Most of the diagrammatic sections of the London Basin give a very exaggerated idea of the dip. This is unfortunate, but, I am afraid, unavoidable, as in any ordinary sized text-book diagram the dip would not be appreciable if drawn to a true scale.

The slopes are—

		O.D.	Distance, Miles.	
Top of Chalk at	Stockwell	− 174	—	
Ditto	Streatham	− 196	3 =	fall of 7′ per mile.
Ditto	Waddon	+ 26	3½ =	rise of 63′ do.
Surface of ground,	Russell Hill	+ 342	2 =	„ 158′ do.
Ditto	White Hill	+ 762	5½ =	„ 77′ do.

The heights are, of course, measured from Ordnance Datum. It seems obvious that no other datum line should be used, but diagrams are occasionally met with in which the *surface* appears as a horizontal line and the depths are measured from that, producing extraordinary apparent flexures of the strata under London. Nothing could be more misleading than such a method.

This disturbance of the beds, slight as it is, has resulted in the production of a number of small faults, running E. and W., as well as N. and S. Slickensides are numerous, showing in some cases vertical and in others horizontal shifting. This was pointed out by Evans, who found several instances of reversed dip in his line of section. That numerous faults occur under London is well known, inequalities of the top of the Chalk having been proved by many borings.

The thickness of the Chalk south of London seems a debateable matter. Mr. Jukes-Browne, in "The Building of the British Isles," p. 291, says "A consideration of the variations in the thickness of the Chalk, as proved by deep borings in the London Basin, shows that the Chalk is thinnest beneath or near London, and that it thickens *in every direction* from that centre."

With this Prof. Barrois seems to agree, but I venture to think in this respect both these eminent geologists are wrong, and that there is a distinct local thinning due S. of London. Mr. Jukes-Browne bases his conclusion on the fact that at various places around London well-borings have proved the Chalk to be thicker than under London itself, but he gives no boring on the South between East Horsley and Chatham, where it is 817 ft. and 682 ft. thick respectively, but these places are 45 miles apart. The average thickness under London is 650 ft., whereas on the South, at Streatham, it is but 623 ft., while at Caterham Waterworks it is only 369 ft. at the most, probably only 349 ft., as there is some doubt about the position of the base. These are the only two borings which go through the Chalk from top to bottom. Then again, as one goes south, the various Tertiary outliers and also the Clay-with-flints are found to lie on lower and lower zones of Chalk. For instance, at Warlingham (Tithe pit) the underlying Chalk is that of the zone of *Micraster cor-anguinum*, at Worms Heath that of *M. cor-testudinarium*, and at Willey Heath, a little north of the above-mentioned Caterham boring, that of *Holaster planus*. This goes to prove that a slight 'Wealden' anticline existed in Tertiary times from which a spur ran out northwards towards London, and that the main E. and W. movement took place later, when the Tertiary beds were affected as well.

Mr. Evans estimated the thickness at 515 ft., but this does not include the mile between the Tertiary border and his cutting No. 1. Allowing a proportionate amount, 80 ft., for that, it gives us a thickness at Croydon of 595 ft., which is about what we might expect on my theory.*

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* Since the reading of the paper Mr. Whitaker has very kindly furnished me with the details of the new boring of East Surrey Waterworks at Purley. Here the Chalk is shown to be about 462 ft. thick. Adding 122 ft., the difference O.D. between top of Chalk in boring (213 ft.) and Russell Hill (342 ft.) close by, we get 584 ft. for the full thickness, another proof of the local thinning, while the discovery of Marsupites at Russell Hill proves that here the Chalk has suffered little, if any, post-Tertiary denudation.

It is usually considered that on the southern part of the area ıe Upper Chalk has been entirely removed, but I believe it overs the whole area (except where cut through by the valleys) nd that the zone of *Holaster planus* forms the crest of the scarpment. If we take Mr. Evans's estimate of the thickness of ıe Lower Chalk at 190 ft. and the Middle Chalk at 75 ft. (and is figures have been generally accepted), together they amount) only 265 ft. and there is usually plenty of room for this every- here along the escarpment. The fossils also bear out this view, ır wherever we have found a pit at a high elevation it has proved) be not lower than *Holaster planus*-zone.

From the crest of the escarpment, which is usually over oo ft. O.D., a tableland slopes gently down in a northerly direc- on, and is largely covered by clay-with-flints. This slope is cut ıto by a number of deeply incised valleys having the same eneral northerly course, that at first sight appear to be the esult of ordinary stream-erosion. These valleys, however, are uite waterless, which fact, together with the steepness of their ides, has attracted much attention, and the matter is discussed t some length in the "Mem. Geol. Surv. Cretac. Rocks," vol. iii, ı. 418 *et seq.* In their formation Mr. Jukes-Browne attributes onsiderable importance to the protection afforded by "clay- overs," but agrees (p. 424) with Mr. Clement Reid* that 'Among the final stages of erosion the frozen condition of the round during a part of the Glacial Period, and the consequent requency of floods, as described by Mr. Reid, was no doubt ırgely contributive to the deep excavation of the terminal alleys in the Chalk districts."

To this theory the following objections may be urged :—

(1.) Granting that the ground may have been frozen and herefore impervious, and that the thaw in spring was sudden, it eems hardly likely that the gathering ground to the south was f sufficient extent to afford streams of the necessary power, ecause it must be remembered that most of these deep valleys re not cut back to the escarpment, so they have evidently not een beheaded by its recession, and therefore they can never ave been longer than at present. The Devil's Dyke, near righton, which Mr. Reid attributes to this cause, is an "obsequent" alley trenching the escarpment only, and therefore its gathering round must have been very small indeed.

(2) If they were due to that cause alone, sufficient time has lapsed since the passing away of Glacial conditions for the emoval of such prominent features, considering that Chalk is so oft a rock.

(3) Dry and steep-sided valleys, (and even underground treams) are found in many limestone districts owing to the easy

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* *Quart. Journ. Geol. Soc.*, vol. xliii, p. 364.

solubility of the limestone and the frequency of joints and fissures. The carboniferous limestone affords numerous examples.

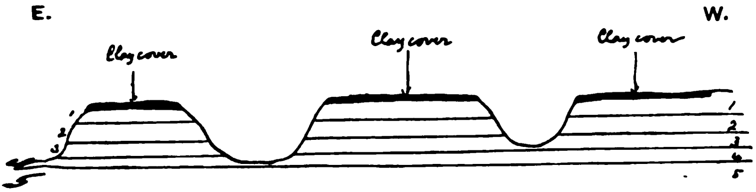
(4) The theory supposes such valleys to be entirely post-glacial, but some chalk valleys are probably much older, e.g. the remarkable V-shaped valley in the chalk near Portrush, Antrim, which is filled with Tertiary basalt, and therefore undoubtedly pre-glacial.

My own view is that these dry valleys are not valleys of corrasion at all, but are due to the simple dissolution of the chalk by surface water, the intervening ridges owing their existence to the protection of a clay capping. Without discussing the origin of the clay-with-flints and brick-earth, about which authorities differ, let us imagine a gently sloping tableland of chalk covered with an impervious clay. The course of the streams would be determined by inequalities of the ground and would have a general parallel direction. The channels would be then gradually deepened until the chalk was reached, when the water would begin to be absorbed by that porous rock. As the area of bare chalk increased, more and more water would be absorbed until a time came when all the water would disappear and the valley would become a dry one, except in very wet seasons. Such temporary streams are called "bournes," or in some districts "nail-bournes" or "winter bournes." The Caterham Valley furnished a notable instance of this in the early part of 1904.

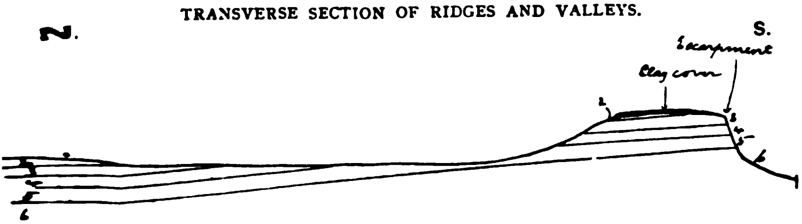
Rain would continue to be shed off the impervious clay surface, but on reaching its margin would immediately sink into the chalk. How large a quantity of water is absorbed is shown by Mr. Baldwin Latham, who found that 11·18 in. passed through his percolation gauge at Croydon out of a total rainfall of 26 in. Rain-water, moreover, is a powerful solvent of chalk, the average temporary hardness being about 14 grains per gallon. The effect would be to remove large quantities of chalk in solution, resulting in a lowering of the surface, and so gradually a valley would be eaten out flanked by ridges protected with clay. These remaining at the original elevation of the whole surface serve as a measure of the amount of excavation. All these flanking ridges have this clay capping, which crops out at a similar elevation on each side of the valley. The difference of absorptive power of the two formations is most remarkable. In March of this year we traversed the clay-capped ridge between Coulsdon and Kenley, on which Welcomes Farm stands, and could hardly get across the fields for standing water. Directly we reached the chalk at the brow of the ridge the wet soil ceased, and the bottom of the valley was "as dry as a bone." As might be expected on this theory, the floor of these valleys is thickly covered with unrolled flints, among which many fossils can be found, and in places, as at Smitham Bottom, for instance, thick masses occur of what my friend Mr. F. J. Bennett calls "vertical" or "residual" drift, consisting of "pellety" chalk, composed of small rounded grains of pure soft chalk, the evident result of this mode of weathering.

These clay-capped ridges also account for our finding so many chalk pits in linear contoured series as already mentioned, for in a great number of cases the pits lie at the brow of the ridge just below the clay-with-flints. In the list (p. 200) such pits are distinguished by an asterisk; they number 109. Most of these small pits have been opened by farmers to obtain chalk for marling the land ("Mem. Geol. Survey Cret.," vol. iii, p. 391), and as all the land requiring this treatment lies on high ground this position would naturally be the most convenient, the cost of transit being reduced to a minimum.

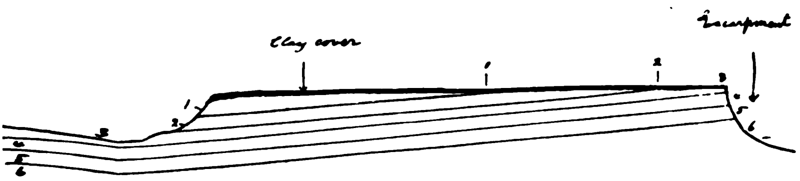
A study of the 1-in. Geological Map will show how intimately the area of the clay-with-flints is connected with the valley system, and the following sections further assist in explaining the connection:—



TRANSVERSE SECTION OF RIDGES AND VALLEYS.



LONGITUDINAL SECTION OF VALLEY.



LONGITUDINAL SECTION OF DIVIDING RIDGE.

1. Zone of *Micraster cor-anguinum.*
2. Zone of *Micraster cor-testudinarium.*
3. Zone of *Holaster planus.*
4. Zone of *Terebratulina gracilis.*
5. Zone of *Rhynchonella cuvieri.*
6. Grey Chalk.

It is most unfortunate that the Government continues to iss these maps on the *old* 1-inch Survey, which is now nearly century old and quite out of date in many of its details, while th absence of contour-lines is a great drawback.

Another great hindrance in the path of the field worker due to the chaotic condition of the nomenclature of the fossil. One would have thought that the natural difficulties of the subje were sufficient without the raising of artificial ones, and I wa very glad to hear the severe remarks made on this subject b Dr. Smith Woodward in his Presidential Address of this year.

I am sure this confusion is doing harm to the science, n only by discouraging beginners, but by adding to the difficulti of those who have got beyond that stage; and I hope that th authorities will soon come to some agreement on the subject. adopt the names used by Dr. Rowe in his Papers so as to ensu uniformity.

OUTCROP OF ZONES.

THE GREY CHALK.

Zones of Holaster subglobosus and Actinocama plenus.

These Zones are to be met with only in pits in the face of escarpment of the North Downs. The quarries are numer and many of them are very large and well known, and of c siderable commercial value, but I have not given them m attention because they are described with considerable deta Vol. ii of the "Geol. Surv. Mem. Cret. Rocks."

The chalk is massive and clayey, yellow when dry, but tinctly grey and very sticky when wet, and the surface o becomes very dark on weathering. There are no flints, nodules of Marcasite are very common.

The principal pits are Brockham (No. 212), Betchw (No. 213), Reigate (No. 223), Merstham (No. 158), and O (No. 153).

Zone of Rhynchonella cuvieri.

This occurs above the Grey Chalk all along the escarpm and all the above-mentioned pits show it in their upper pa Its occurrence N. of the escarpment at Public Hall pit, Caterh (No. 139) and possibly at Whyteleafe (No. 119) suggests t some of the dry coombes are cut down sufficiently deep as expose it, but there are no pits exactly in the position to prove It is a hard, white, gritty chalk, somewhat lumpy, and weathe into small flaky pieces, so that it can be readily distinguished fro the beds below. It contains very few flints.

Zone of Terebratulina gracilis.

This Zone is not always easy to separate from the one below, either lithologically or zoologically. It occurs in the highest parts of the large pits of the escarpment and forms the floor of the upper parts of most of the dry coombes. The chalk is not quite so hard or gritty and somewhat more marly than that of the preceding zone. Flints occur but are not plentiful. There are not many sections of this zone in Surrey, the best being Slines Oak (No. 127), Whyteleafe (No 119), Rose and Crown (No. 113), and Boxhurst (No. 209).

Zone of Holaster planus.

I have already said that I believe the crest of the North Downs is formed by this zone. Taking the pits from West to East we have Boxhurst pit (No. 209), 585 O.D., in the face of the scarp and 50 feet below its crest; at Hill-top pit (No 165), 720 O.D. at the very brow, we did not find the typical zone fossils, but the large size of the Terebratulæ found is suggestive of this zone; Willey Heath pit (No. 168), 650 O.D., half a mile north of the crest which is here (at Willey Farm), 730 O.D., affords an unmistakable fauna (see p. 215), and, lastly, Tillingdown pit (No. 140), one mile north of the crest, is at 600 O.D., being near to, and 100 feet above, the Public Hall pit in the *R. cuvieri*-zone. In all these cases there is sufficient height above the base of the chalk to allow of its occurrence, while it is even quite probable that the highest points of the Downs are patches of the zone of *Micraster cor-testudinarium*.

This and the two succeeding zones are exposed either at the bottom or on the flanks of all the valleys, where their position is determined by the distance from the escarpment and the relative height of the outcrop above sea-level.

At this horizon there is often a pronounced terrace which is possibly formed by the outcrop of the "chalk-rock," *e.g.*, below Chipstead cutting (No. 84), and between Waddington pit (No. 107) in *M. cor-testudinarium*-zone and In Wood Pit (No. 104) in *T. gracilis*-zone. The chalk is hard with numerous scattered flints, a large proportion of which are spongiform.

At the four pits first mentioned and also at Greathill Shaw (No. 128) it is covered directly by clay-with-flints.

Zone of M. cor-testudinarium.

This zone is almost entirely confined to the higher parts of the flanks of the valleys, and therefore its outcrop is a long narrow sinuous band following their slopes and outlines. In many places it reaches to the crest of the intervening ridges, and is then overlain directly by the clay-with-flints. The chalk is rather yellow in colour, hard and somewhat gritty, with numerous fli[illegible]ts, mostly scattered, and often spongiform. Fossils are plenti[illegible]ul, especially *Spondylus spinosus*, *Echinocorys vulgaris* var. *gibb[illegible]us*, and *Micraster præcursor*, the varieties of which present a ser[illegible]es of almost bewildering gradations in elaboration of ornamen[illegible]t. Number of Sections 15. The most interesting pits are Sto[illegible]t Nest (No. 95), Purley Station (No. 30), Chipstead cutti[illegible] (No. 84), Woottonga (No. 122A), and Tithe Pit (No. 118).

Zone of Micraster cor-anguinum.

This has a broader outcrop than any other zone, occurri[illegible] over most of the northern part of the area, and is apparently [illegible] considerable thickness. Where it forms the crest of the ridges [illegible] is usually covered by clay-with-flints, but for the most part it bare except for a thin covering of soil and turf. The chalk [illegible] very white, soft, and absorbent, and breaks with a peculiar co[illegible]choidal fracture. Flints are very abundant, mostly in regul[illegible] courses, generally nodular but with occasional thick tabu[illegible] layers. Fossils are not so plentiful as in the zone below, a[illegible] sometimes are very scarce. The most interesting pits are Sutt[illegible] (No. 5), Haling (No. 29), Bishop's Pit (No. 58), and Addingt[illegible] Lodge (No. 23). Total number of Sections 40.

Zone of Marsupites testudinarius.

It has hitherto been considered that this zone is entir[illegible]ly absent in Surrey, no specimens of this fossil ever having b[illegible]en recorded from the county. In 1876 Prof. Barrois, judging prin[illegible]cipally by the lithological characters of the chalk, thought it mi[illegible]ht be present at Guildford. Dr. Hinde,[*] judging from the la[illegible]ge size of the *Porosphæra globularis* he found at South Croyd[illegible]n, concluded, by a very sound piece of reasoning, that it had [illegible]ot long been removed by denudation. Mr. Jukes-Browne,[†] w[illegible]ile suggesting that it might possibly be present in the western [illegible]art of the county, records his opinion that it had most prob[illegible]ly been denuded before the deposition of the Tertiaries. [illegible]his emphasises the importance of the following:

DISCOVERY OF MARSUPITES IN SURREY.

On May 15th, 1904, soon after the publication of the *Sur[illegible]y Memoir*, two members of the Battersea Field Club, Mess[illegible]s. Wright and Polkinghorne, were cycling up Russell Hill, ne[illegible]r Purley, and, as often happens when going uphill, they g[illegible]t separated. Mr. Wright dismounted, and began to examine t[illegible]e chalk thrown out of a sewer-trench which was being made [illegible]t

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[*] *Journ. Roy. Micro. Soc.*, 1904, p. 1.

[†] *Mem. Geol. Survey Cret. Rocks*, vol. iii, p. 179, *et seq.*

that time. In a few moments he was surprised to find a *Marsupites*-plate. Further search resulted in the finding of more plates by both of them, Mr. Polkinghorne having by that time come up and joined in the search. They acquainted Mr. Dibley of their discovery, and he subsequently visited the spot with them and further plates were found, which were exhibited at the meeting of this Association on June 2nd, 1904. Then Dr. Hinde, hearing of this, and living in the neighbourhood, took up the search with great zest, and the result was a masterly paper by him which appeared in the *Geol. Mag.* for October, 1904. It is noteworthy hat Mr. Wright had, as far back as 1901, found a plate of *Marsupites* in flint, but that being from surface soil, no importance was attached to it at the time. This discovery of *Marsupites* completely revolutionised our ideas of the Upper Beds in Surrey, because if the zone was present at Russell Hill, which is 1½ miles rom the Tertiary outcrop, and only 340 ft. above O.D., why should it not occur elsewhere? It was obvious that the pits near he Tertiaries should be carefully searched, and thus I came to compile my list of chalk pits and begin a systematic search. In this work I have had the advantage of the help of Mr. W. Wright and Mr. Walter Johnson, two men who, as the joint authors of "Neolithic Man in North-East Surrey," obtained an accurate topographical knowledge of the district whilst engaged on that work, and without whose encouragement both in the field and in the study this paper would not have been written.

This search was highly successful, for we have proved the presence of the *Marsupites*-zone at no less than twenty-two places, extending from Addington to Headley, a distance of 14 miles, and I fully believe that it was once an entirely continuous sheet over the whole northern part of the district. Going round the Tertiary border, the only place we have not been able to find it is between Carshalton and Sutton, but in this locality there are no pits in a favourable position, and the configuration of the ground is against its preservation. The *Marsupites* Chalk is soft and seems easily weathered, and as I do not suggest any great thickness for it, it is obvious that it may have been denuded in some places subsequently to the removal of the overlying Tertiaries. In most places where the Tertiary Beds form an escarpment with a pit close to the outcrop, there we have found proofs of its presence. For instance, at Beddington, where the Thanet Sand forms a tongue-shaped hill, The Dell pit (No. 11A) yields *Uintacrinus*, while in the pit (No. 50) at the tip of the similar ridge at Howell Hill, near Ewell, we found both *Marsupites* and *Uintacrinus* plates. Two other pits on the western flank of the same hill (Nos. 45 and 50) both yielded *Uintacrinus* plates.

The finding of *Marsupites* zone at a distance from the Tertiary border depends upon two things: 1st, the slope of the surface, which, when it exceeds the angle of dip, may bring it in, in the form of outliers, probably in places from which the Tertiaries have not been very long removed; and 2nd, the presence of small faults, of which there are numerous indications.

The Chalk of this zone is very white and quite soft with very few flints. That of the *Uintacrinus* band has the same lenticular horizontal jointing which gives it the almost false-bedded appearance so noticeable in the Margate cliffs, while the beds of the *Marsupites* band are more evenly and more thickly bedded. Fossils are fairly plentiful and easily cleaned. Not only are [illegible] name-fossils found, but also the other species characteristic [illegible] this zone elsewhere. *Antinocamax verus* and *A. granulat* *Micraster cor-anguinum*, var. *rostratus*, the nipple-shaped he of *Bourgueticrinus*, while the two shape-variations of *Echinocor* can be absolutely matched with those from Margate. The mo interesting sections are Coombe Farm (No. 12), Ballards (No. 13 Great Woodcote (No. 26), Banstead Station Cutting (Nos. 3 and 39), Medical College (No. 49), Clay Lane, Headley (No. 189).

FOSSILS.

Many of the smaller pits are in bad condition for collecting from, being frequently partly filled with rubbish and the chalk covered with rain-wash, Protococcus, and mosses. In such cases specimens were, naturally, few. Every fossil recorded was found and its position noted by one or other of us. This is of the greatest importance in all zonal work, as a large pit may easily range into two or more zones. A list of the fossils found in certain representative pits is given on p. 215.

The next point of interest is the value of zonal collecting. When Dr. Rowe heard of the discovery of *Marsupites* he said "Search for *Uintacrinus*, if you have *Marsupites* you ought to find the *Uintacrinus* band below it." Out of the twenty-two exposures of this zone nineteen have afforded *Uintacrinus* and seven have yielded *Marsupites* as well, showing that we are at the junction of the two bands.

Uintacrinus is a splendid fossil for zoning purposes, especially in chalk pits. Although the test is easily broken, so easily that I despair of ever finding a specimen even remotely approaching completeness, yet each fragment of a plate can be easily recognised by the V-shaped notches on the inner surface. In pits which are small, dirty, or badly weathered, this is often one's only reliable guide. It is seldom to be found on the surface, but a few minutes' work breaking up the Chalk into fragments will generally reveal it if we are in the zone.

Following Dr. Rowe's example, I have not definitely zoned a pit on the evidence of the ossicles alone but always on the plates of the test.

One may fairly ask why *Marsupites* has not been found re if the zone has so large an exposure as I claim for it. reasons are, I believe, firstly, that most of the work done in ey has been confined to the escarpment and only one cross of section—the Caterham Valley. Mr. C. Evans, Mr. ley, and the Survey all deal with that district. The only r sections described in the *Memoir* are those at Stoats Nest lsdon) and the Chipstead Cuttings, and even those are not way. Secondly, search has been mostly confined to large ries and lime-works, which for convenience of transport are rally placed in the valleys, and therefore in the most unlikely tion to find the higher beds.

As to the possibility of its occurrence west of the Mole, I e to work that district in a similar way in the near future. As zone occurs so near that valley as Ashtead and Headley e is a strong probability of its presence still farther west.

I have now to tender my hearty thanks to the following other tlemen for their kind help in the preparation of this paper: Messrs. E. T. Newton and H. A. Allen, of the Museum of ctical Geology, who have named some of the fossils; to Mr. D. Lang, of the British Museum (Natural History), who has efully identified many of the Cyclostomatous Bryozoa; and ve all to Dr. A. W. Rowe, who has named and zoned many of specimens, whose advice and encouragement have been aluable, and whose papers on the coast sections have nulated me to essay this paper, which is an attempt to carry inland the work that he has done so well on the coast.

A LIST OF CHALK PITS IN NORTH-EAST SURREY.

The heights are estimated from the nearest figures marked on 6-in. Map. The pits marked * are situated high up on the flanks of the valleys and just under the Clay-with-flints. In Marsupites zone, M. denotes Marsupites band; U. denotes Uintacrinus band.

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a. zone. F	M. zone. U.M.
		SHEET 13 S.E. (6-INCH)—CHEAM TO CARSHALTON.							
1	170	At Lower Cheam, adjoining cricket ground, disused, totally overgrown with large trees.	...	...	...	...	...	...	...
2	160	300 yards W. of No. 1, enclosed, disused, and overgrown (100 yards N. there is a "bourne-hole" in Love Lane)	...	...	...	...	...	...	...
3	170	Side of road entering Cheam, private, overgrown	...	...	...	...	...	...	...
4	190	Outside Cheam Station, overgrown, shallow	...	...	...	...	...	...	...
5	190	Near Sutton Station, on road to Carshalton. Very fine old and deep pit, but little worked now, recently bought by Sutton Water Co. Said to be the pit from which came the lime used in building St. Paul's Cathedral (see "Victoria History of Surrey"). Chalk white, hard, and chippy. Many bands of flint in regular courses, mostly nodular, also two strong tabulars. Cortex of flints, thick and rough, simulating fossils. At S.W. corner a diagonal tabular is seen cutting a vertical joint which it displaces about 3 ft.	...	...	...	...	...	F.	...
6	180	150 yards N. of bridge over railway crossing Carshalton Road. Small and completely overgrown	...	...	...	...	...	...	...
7	187	At above-mentioned crossing, about 12 ft. deep, fossils few, a thick (4-in.) tabular flint-band	...	...	...	...	...	F.	...
8	170–190	At Park Hill Cottage, Carshalton, a large pit now used as a garden, massive well-bedded chalk with many layers of nodular flints in regular courses, and one well-[illegible]ed tabular. Chalk well-weathered but fossils scarce	...	...	...	...	...	F.	...
8a	220	Sewer cutting, near [illegible] railway, quarter mile E.S.E. of No. 8, S. of Carshalton Park ...	...	...	...	...	...	F.	U.

Sheet 14 S.W.—Croydon District.

9	180	*S. of* Duppas Hill, shallow, completely overgrown ...		...
10	220	In Coombe Lane, corner of Park Hill Road, close to water-tower. A large old pit, very small portion now accessible. Shows junction with Thanet Sand with typical "Bull head" bed of flints, 3 ft. below which is a very thick tabular layer ...		U.
11	300	Croham Lane Pit. Large pit, disused for fifteen years. Just under Tertiaries, chalk blocky, with many flints, in layers and scattered. Fossils few ...	F	...
11A	120	The Dell, Beddington, very old, disused, not far from Tertiaries, badly weathered ...		U.
11B	225	Selsdon Road Station Pit, small, not marked on 6-in. Map. Chalk very white, but iron-stained, flints in courses, fossils few ...	F	...

Sheet 14 S.E.—Addington District.

12	291	Coombe Farm Pit, Shirley. Is in the narrow tongue of chalk (300 yards wide) running E.N.E. between the Tertiaries of Addington Hills and the main mass. Chalk thickly bedded with many scattered flints ...	F	U.
13	360	Ballard's Pit. South side of Addington Hills. Massive chalk with few flints ...		U.M.
14	350	At bottom of Addington Hill, overgrown ...		...
15	340	In Addington Park, not visited ...		...
16	290	At Addington Vicarage, full of trees, overgrown ...		...
17	329	Still's Pit, between Addington and Castle Hill Farm, half mile from Tertiaries, very small, disused ...		U.
18	237	At Kent Gate, a gravel pit, disused ...		...
19	290	Fox Hill Pit (in Kent), very massive beds with strong flint bands, fossils scarce ...	F	...

Sheet 20 N.E.—Farley District.

20	500	*Selsdon Park Pit. An old pit, hidden away in a wood, moss-grown, chalk massive ...		M.
20A	480	*Borough Farm Pit, Sanderstead, small pit not marked on 6-in. Map, much iron-staining	F	...
21	480	*E. of Selsdon Park, overgrown with yew trees ...		...
21a	500	*W. of Moorcroft, Farley Green ...		...
22	500	*At Haggler's Dean ...		...
23	480	*Addington Lodge Pit, three-quarter mile S. of, and 150 ft. higher than No. 17, with more massive chalk and distinct bands of flints. As these bands are apparently horizontal there is possibly a fault between the two pits. Several large pipes ...	F.	...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a. zone. F	M. zone. U.M.
24	500	*At "Lime Kiln," Farley Dean. Large old shallow pit, now a rabbit warren	...	...	...	...	...	...	..
25	500	*E. of Three-corner Grove	...	...	...	...	...	...	...
		SHEET NO. 20 N.W.—PURLEY DISTRICT.							
26	330	At Great Woodcote. Very interesting pit, nearly circular. A fault running N. and S. divides the pit into two nearly equal parts. We found *Marsupites* on the E. and *Uintacrinus* on the W. side of the fault	...	...	...	...	...	...	U.M.
27	360	Half mile S.E. of above, entirely built around, inaccessible	...	...	...	...	...	...	...
28	330	Near Russell Hill. The sewer cutting where *Marsupites* was first found (see p. 196 also Dr. Hinde, *Geol. Mag.*, Oct., 1904). The lower part towards Beddington probably cuts down into the *M. cor-anguinum* zone. For fossils see p. 215	...	...	...	...	..	F.	U.M.
29	200 base	Haling Pit, Croydon. A large pit where Godwin-Austen's granite boulder was found. Chalk in regular courses, fossils not plentiful, but often well preserved	...	...	...	...	?	F.	...
30	270 base	Purley Station Pit, very large with several pipes. Chalk hard, fossils most numerous at North end. Found a *Micraster* of *H. planus*-zone type	...	...	...	?	E.	...	...
31	426	Purley Downs Golf-links Pit, very small, fossils few	...	...	...	...	...	F.	...
32	350	On Riddlesdown, now being filled up	...	...	...	...	...	...	...
33	273	At Riddlesdown Tea-gardens, very old, rubbly and dirty	...	...	...	...	...	...	...
34	290	N. of Kenley Station, very rubbly	...	...	...	...	...	...	...
		SHEET 19 N.E.—BANSTEAD DOWNS.							
35	340	600 yards W.S.W. of Sutton reservoir on Brighton Road, now used as a golf green	...	...	...	...	...	...	...
36	300	Belmont Station pit, now disused, partly built over, flints numerous	...	...	...	...	...	F.	..
37	400?	Banstead Railway Cutting, No. 1, portion E. of Reigate Road, runs N. and S. on a curve. A strong flint tabular rises from the base close to bridge and runs out at top of cutting farther N.	...	...	...	...	...	F.	...

39	400?	Banstead Railway Cutting, No. 3, between Banstead Station and Schools		[illegible]
40	420	Opposite Hundred Acres Asylum, now filled up		...
41	440	Fairlawn Pit, near Croydon Lane, considerably overgrown		U.
41*a*	...	Not marked on 6-in. Map, at Sheep Farm, S. of 41, very small		...
42	400	In field 400 yards W. of Oaks Corner, shallow, overgrown		...
43	330	At Little Woodcote, shallow but well weathered lenticular chalk, flints few. *Uintacrinus* plentiful		U.
43*a*	240	Sewer cutting at Wellfield	F.	...
44	430	Big Wood Pit, Woodcote Grove. Chalk white, with a strong flint nodular band, fused in places into a tabular. Fossils scarce	F	...
44*a*	450	At Woodcote Grove, chalk similar to No. 43, but much moss-grown		?

SHEET 19 N.W.—EPSOM AND EWELL.

45	160	Nonsuch House Pit, Ewell. Very small but clean pit, close to Tertiaries. Very few flints, horizontal slickensides		U.
46	210	In Epsom Recreation Ground, small and turf-grown		...
47	200	Near Pit Place, Epsom, overgrown, full of trees		...
48	230	Near Pit Place, Epsom, overgrown with turf		...
49	280-330	Medical College Pit. A large pit, chalk of upper part (about 30 ft.) is soft with fauna characteristic of *Uintacrinus*-band, the lower part is harder and belongs to zone of *M. cor-anguinum*. Between them is a peculiar iron-stained clavey layer, probably washed in from surface. About 6 ft. below this is a regular layer of large flints. There is a smaller excavation in the floor of the pit which contains many *Echinoconus* and an *Echinocorys* of *M. cor-anguinum*-type. For fossils see p. 215	F	U.
50	210	At S. end of Tertiary tongue at Howell Hill. A small, very old pit, much overgrown and full of elder trees. Small exposures at top of talus show soft chalk with *Marsupites* and *Uintacrinus*		U.M.
51	210	Priest Hill Pit, quarter mile S. of No. 50. A small pit, but fairly clean. Junction of M. and U. bands		U.M.

No.	Height above O. D.	DESCRIPTION.	Grey Chalk.	R. c. zone.	T. g. zone.	H. p. zone.	M. c-t. zone.	M. c-a. zone.	M. zone.
			A	B	C	D	E	F	U.M.
		SHEET 18 S.E.—LEATHERHEAD AND ASHTEAD.							
52	120	Rowhurst Brickyard on Tertiaries	...	...	...	...	...	...	...
53	190	N. of St. John's School, Leatherhead. Deep pits, now grassed over. Called "Old Gravel Pits" on 6-in. Map	...	...	...	...	...	...	...
54	240	At "The Marches," on main road. A wide shallow pit, chalk rather hard, fossils scarce. Flints in bands, some of enormous size	...	...	...	...	...	F.	...
55	200–240	Ashtead Rifle Range Pit. Large but very old pit, used as a miniature rifle range. Chalk soft but much covered with Protococcus and mosses, difficult to collect from. *M.* band at top, *U.* band at bottom; thickness about 40 feet	...	...	...	...	...	...	U. M.
56	290	In Chalk Lane, near Ashtead Church. Very small but interesting, about 8 ft. deep, both *Marsupites* and *Uintacrinus* found close together	...	...	...	...	...	...	U. M.
57	290	Quarter mile S.W. of No. 56, overgrown, full of large beech trees...	...	...	...	...	...	...	...
57A	350	Roman Road Pit, close to the Ermyn Street. Small, fossils not numerous	...	...	...	...	...	F.	...
		SHEET 19 S.W.—EPSOM DOWNS.							
58	280–330	Bishop's Pit, E. of Ashtead Park, corner of Headley Lane. A large pit, still in use. Close to Tertiaries. Fossils not plentiful, but occasionally well preserved. One well-marked flint nodular with three ill-defined ones above it, about 6 in. apart. Possibly there is a capping of *Marsupites*-zone here, as one specimen of the *sub-pyramidatus* variety of *Echinocorys* was found. There are also two peculiar masses of chalk débris shown in section	...	...	...	...	...	F.	?
59	350	Headley Lane Upper Pit 300 yards S. of No. 58, at corner of side road. Large but shallow, chalk soft with powdery surface, fossils scarce	...	...	...	...	...	...	U.
60	330	Close to the Ermyn Street, half mile S.W. of Epsom Grand Stand, overgrown with trees	...	...	...	...	...	...	...
61	420	In Sheep Walk, S.W. of No Home Farm. Very small, badly weathered	...	...	...	...	...	F.	...
62	380	Target Pit, at Epsom Rifle Range, near Grand Stand. Small pit with band of very large flints near the top, chalk much jointed, slightly faulted with slickensides ...	...	...					

		but *Marsupites* found			"	...
65	500	*At N.W. corner of Shelvershill plantation, completely overgrown...				...
66	520	*At E. end of Shelvershill plantation, small pit about 15 ft. deep, disused, chalk hard and massive, with conchoidal fracture, flints numerous, but fossils scarce			F	...
67	520	*At angle of lane, 250 yards S. of Shelvershill plantation, completely overgrown ...				...
68	500	300 yards N. of Tumble Beacon. Small pit, disused, but fair condition, chalk much jointed, with a layer of very large flints, fossils scarce				...
		SHEET 19 S.E.—BANSTEAD AND CHIPSTEAD.				
69	500	*100 yards N. of Green Lane. Thick undergrowth and trees				...
70	500	*N. of Highhurst Wood, Waterhouse Lane				...
71	500	*Kingswood Station small pit, a small exposure			F	...
72	500	*Kingswood Station pit, W. of No. 71. Rather deep semi-circular pit, chalk very white, but much stained from surface soil, one very large pipe. Flints in regular bands, fossils rare			F	...
73	500	*In Holly Lane, E. of Garratt's Hall				...
74	500	*One-sixth mile S.E. of No. 73				...
75	500	*Pit Barn Pit, one-sixth mile S.W. of No. 73. A small pit with a fine, clearly defined pipe			F	...
76	500	*Read's Rest Pit, W. corner of Lunch Wood. A small exposure chalk similar to No. 75			F	...
77	500	*Lunch Wood Pit, S. corner of Lunch Wood				...
78	480	*N. of The Shrubbery, Banstead Place...				...
79	480	*S. of The Shrubbery, Banstead Place				...
80	500	*One-sixth mile N.W. of No. 81				...
81	500	*At Park Downs Cottages. Not now used, but clean surface; Chalk very white, fossils very scarce. A thick tabular is present with a nodular band 6 ft. above it			F.	...
82	500	*Above Long Plantation, Chipstead Bottom				...
83	370	Small cutting, N. of Chipstead Station. See "Memoir," vol. iii, p. 174...		E.		...
84	380	Chipstead Cutting, S. of station. See "Memoir," vol. iii, p. 174. I differ from the Survey in placing this cutting (with the exception of a few feet at the S. end) in the zone of *M. cor-testudinarium*, as all the *Micrasters* we found were of the type of that zone. About 20 ft. below the floor of the cutting is a prominent terrace on the hill-side, possibly formed by the "Chalk-rock." For fossils see p. 215.	D.	E.		...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk.	R. c. zone.	T. g. zone.	H. p. zone.	M. c-t. zone.	M. c-a. zone.	M. zone.
			A	B	C	D	E	F	U.M.
85	430	*In Hazelwood Lane. Small road-side pit about 50 ft. above this cutting; flints numerous, but fossils not so. Capped by clay-with-flints	...	...	...	...	E.	...	...
86	480	*Starrock Wood Pit Chalk rather soft and white. Numerous flints, many of them peculiar, long, thin, and cylindrical. *Micrasters* of type of lower one-third of *M. cor-anguinum*-zone. This, with the two preceding sections, forms a fairly continuous vertical section of about 100 ft. in depth	...	...	...	...	...	F.	...
87	480	*At Starrock Shaw, overgrown with trees	...	...	...	...	...	...	...
88	480	*S. of Starrock Shaw, overgrown with trees	...	...	...	...	...	...	...
89	460	*At Portnall's Farm	...	...	...	...	...	...	...
90	470	*S. of Portnall's Farm	...	...	...	...	...	...	...
91	440	At Church Shaw, E. of Chipstead Church. Very old deep pit, with no road approach ("draw-pit" type), full of trees, including a large yew	...	...	...	...	...	...	...
92	500	*At Peterhole Shaws, E. of Brighton Road	...	...	...	...	...	...	...
		SHEET 20 S.W.—COULSDON DISTRICT.							
93	365	At Hooley Farm. Very small road-side section, fossils scarce, but an abundance of spongiform flints	...	...	...	D.	...	...	...
94	480	*N. of Woodplace Farm. Very old, full of trees	...	...	...	...	...	...	...
95	300–420	Stoat's Nest Pit, near Coulsdon Station. Very large pit, funnel-shaped. A series of cuttings about 5 ft. deep radiate from the narrow entrance, and in these cuttings *Micraster præcursor* of *M. cor-test.*-zone type is very abundant. The chalk is very hard and creamy in colour. Above the cuttings fossils are very scarce, and both nodular and tabular horizontal flint-bands are numerous and close together. See also "Memoir," vol. iii, p. 177.	...	...	...	...	E.	F.	...
96	450	*N. of Marlpit Lane	...	...	...	...	...	...	...
97	500	*S. of Marlpit Lane	...	...	...	...	...	...	...
98	491	At Farthingdown Cottages. Very old, surrounded by yews, a little chalk exposed but fossils very scarce	...	...	...	...	...	?	...

99	500	*One-sixth mile S. of Tollers Farm, old but rather large pit, with a ruined kiln. Chalk white and of medium hardness with nodular bands of flints				F	...
100	480	*At Devil's Den Wood. Very small, overgrown and full of trees					...
101	500	*One-third mile E.S.E. of No. 99. Very old, overgrown and full of trees					...
102	470	*One-sixth mile E. of No. 100. Very small, overgrown and full of trees					...
103	500	*Half mile S.E. of No. 102. Very old, deep, overgrown and full of trees					...
104	375	In Wood Pit, in Old Lodge Lane. Very small road-side section, but with unexpectedly low zonal fauna	C.				...
105	500	*One-sixth mile E. of No. 104. In private ground, apparently overgrown with trees					...
106	490	*One-sixth mile N.E. of Welcomes Farm. In private ground, dirty and overgrown. No fossils					...
107	500	*Waddington Pit. Old, much overgrown, chalk hard and massive, in thick beds, scattered flints, some of large size			E.		...
107*a*	480	*N. of Taunton Farm. A small, old pit, recently re-dug. No fossils					...
108	500	*At Taunton Farm					...
109	500	*One-eighth mile N.W. of No. 110. Very old, quite overgrown					...
110	500	*One-eighth mile W. of Waterhouse Farm. Resembles No. 107. Many of the flints have a soft white outer cortex which peels off easily			E.		...
111	480	*Quarter mile N. of Kenley House. Old, overgrown with yews and elders					...
112	520	*One-eighth mile N. of Neville House. An old pit, but with workable exposure. Flints fairly numerous, many of them spongiform		D.			...
113	300- 450	Rose and Crown Pit, Kenley, See "Memoir," Cret. Rocks, vol. ii, p. 387, vol iii, p. 173, Dibley, *Proc. Geol. Assoc.*, vol. xvi, p. 490	C.	D.			...
114	500	*150 yards N. of No. 113					...
115	500	*100 yards E. of No. 113					...
116	500	*One-third mile S.E. of Kenley House					...
117	400	*Near Joynson's Hill, very shallow and grassed over					...
		SHEET 20 S.E.—WARLINGHAM DISTRICT.					
118	525	*At Tithe Pit Shaw. A rather large pit, occasionally used. The lower part, 5 ft., is damp yellow chalk, rather gritty, fossils plentiful, *M. cor-testudinarium*-zone. Above this is a very white drier chalk with several bands of nodular flints, fossils rather few, *M. cor-anguinum*-zone. There is a small pipe of brilliant crimson brickearth. For fossils see p. 215			E.	F	...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a. zone. F	M. zone. U.M.
119	350–450	Whyteleafe Pit. See "Memoir," vol. ii, p. 387, Dibley, *Proc. Geol. Assoc.*, vol. xvi, p. 490. Very large pit, upper part inaccessible; middle part, rather hard creamy chalk, massive, no flints; lower part, whiter, but otherwise similar. For fossils see p. 215...	...	?	C.	D.	...	...	...
120	530	In the foundations of a house being built overlooking No. 119 numerous *Echinocorys vulgaris* var. *gibbus*, identified by Dr. Rowe as typical shape of *M. cor-testudinarium*-zone	...	...	...	...	E.	...	...
121	520	*One-third mile S.E. of No. 119, at Highlands. Entirely overgrown with trees... ...	...	...	...	...	...	...	...
121*a*	560	*Quarter mile E of Hamsey Green Farm	...	...	...	...	...	...	...
122	560	Quarter mile E. of No. 118. Marked "Old Quarry" on 6-in Map. Is a brickfield. Bricks are of a very bright red. No chalk to be seen	...	...	...	...	...	...	...
122*a*	570	*Woottonga Pit in Bughill Lane, at W. end of Hallelu plantation. Not marked on 6-in. Map. Chalk massive and very hard. For fossils see p. 215.	...	...	...	...	E.	...	...
123	530	*N. of Mount Hopper	...	...	...	...	...	...	...
123*a*	550	*N. of Crow's Wood	...	...	...	...	...	...	...
124	600	Brickfield W. of Blanchman's Farm	...	...	...	...	...	...	...
125	600	*Hallelu Pit, 200 yards S. of Blanchman's Farm, E. end of Hallelu Plantation. Very small, chalk moderately soft, a few very large flints	...	...	...	...	E.	...	...
126	600	*"Inglenook" Pit, quarter mile E. of No. 125. Small and disused but interesting. I have given it this name because the roots of a very large beech overhang, making a cave of respectable size, quite rainproof, evidently used by gipsies who have broken a hole through the roof to let out smoke. Chalk and fossils resemble those in No. 122*a*	...	...	...	...	E.	...	...
127	540	Slines Oaks Lower Pit, near pumping station. Of fair size, still in use. Chalk hard, very few flints. Into this pit there is a great wash of the red Blackheath pebble beds from Worms Heath	...	...	C.	...	...	...	...
127*a*	720	Slines Oaks Upper Pit, about 180 ft. above the lower one, near Nore Hill Pond. Is being worked for the Blackheath pebbles, but the chalk shows in large pinnacles ...	...	...	...	...	E.	...	...

	330	***Greathill Shaw Pit, near Midgeley Shaw.** *Small old pit*, no section but large rubbly talus, with many fossils, evidently junction of T. g. and H. p. zones. A marked *terrace* a little above suggests "Chalk Rock," and above that comes clay-with-flints ...			C.	D.	...		...
129	575	*In Ledgers Park, opposite footpath to Chelsham Church				...	...		...
129a	600	*In Ledgers Park, one-sixth mile S. of No. 129				...	...		...
		(*Nos.* 130 *to* 138 *on Sheet* 28 *N.W. outside the district.*)							
		SHEET 27 N.E.—WOLDINGHAM DISTRICT.							
139	480–520	At back of Public Hall, Caterham. See "Memoir," vol. iii, p. 385, disused, no flints, fossils common on talus, chalk hard and gritty. For fossils see p. 215...		B.		...	...		...
140	600	*Tillingdown Pit, quarter mile E. of No. 139. Disused, now being used as a dust shoot, a small exposure				D.	...		...
141	550–650	Godstone Quarries A large series of excavations in the face of the escarpment, not now worked for chalk and very little for firestone (Up. Greensand) which latter is done by tunnelling. Chalk is much obscured, but scattered fossils can be collected on the talus	A.	B.	C.	...	...		...
142	620	*In Marden Park, quarter mile N.E. of South Lodge. Very old, disused, rubble only ...				...	...		...
143	730	*One-sixth mile W. of Woldingham Church				...	...		...
144	780	Close to Chaldons Farm, "Gravel" pit				...	...		...
145	600–700	Under Hogtrough Lane. Disused, rubbly talus				...	...		...
146	700	*One-sixth mile N. of Nether Court. Small, very old, but with fossils on talus			C.	...	...		...
147	780	One-third mile N.N.E. of No. 145. Small, planted with trees, in private grounds ...				...	...		...
148	580	One-eighth mile S.E. of No. 147. No exposure, grass-grown talus				...	...		...
149	820	*At S.E. corner of Wistler's Wood. Quite overgrown with trees				...	...		...
150	810	W. of Greenhill Shaw, marked "Old Quarry" on 6-in. map, is merely a deep conical *hole* about 40 feet across, now full of trees. As there is no sloping roadway to it, Mr. W. Johnson considers it to be an old draw-pit of the nature of a dene-hole ...				...	...		...
151	850	Quarter mile W. of Flinthouse Farm } Two gravel pits in isolated patches of Blackheath pebble-beds, on the highest ground in the neighbourhood, and on the crest of the North Downs							
152	850	Quarter mile N. of Flinthouse Farm }				...	...		...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a. zone. F	M. zone. U.M.
153	600–800	Oxted Chalk Pits. See "Memoir," vol. ii, pp. 53, 385. Very large pits, lower part consists of typical grey chalk with but few fossils, the *Act. plenus* marl can be traced about half way up the main face with the *R. cuvieri* beds above it. One of the spoil heaps from this zone yielded many fossils	A.	B.	?	...	...	...	...
154	580	Quarter mile S.E. of No. 153. No exposure, grass-grown talus	...	...	...	...	...	...	...
		SHEET 27 N.W.—CATERHAM DISTRICT.							
155	500	*Quarter mile W. of The Gullet	...	...	...	...	...	...	...
156	500	*One-eighth mile S.W. of Grasscuts Shaw	...	...	...	...	...	...	...
157	600	*One-sixth mile S. of Alderstead Farm. Very old, overgrown with trees	...	...	...	...	...	...	...
158	370–490	Merstham Lime Works. See "Memoir," vol. ii, pp. 53, 385. Very large	A.	B.	...	...	...	...	...
159	500	*Ditches Lane Pit, one quarter mile N. of Chaldon Church. Fairly large, not much used; fossils few; flints numerous; many spongiform	...	...	...	...	E.	...	...
160	500	*Quarter mile S.W. of No. 159. Very old, overgrown with trees and bushes	...	...	...	...	...	...	...
161	490	*150 yards W. of No. 160. Very old, overgrown with trees and bushes	...	...	...	...	...	...	...
162	500	*One-eighth mile N. of No. 161. Very old, overgrown with trees and bushes	...	...	...	...	...	...	...
163	610	*S. of Tollsworth Farm, at W. end of Pilgrim's Lane. Large, old shallow pit, very small exposure at brow of escarpment overlooking Merstham	...	...	C.	...	...	...	...
164	650	*In Pilgrims Lane, at Little Willey. Very old, deep pit, overgrown with trees	...	...	...	...	...	...	...
165	720	*In Pilgrims Lane, at Hill Top House. Small, at crest of escarpment, chalk very hard, flints few	...	...	...	?	...	...	...
166	730	*In Pilgrims Lane, near Willey Farm, two pits, both overgrown	...	...	...	...	...	...	...
167	710	One-eighth mile S. of Willey Farm. Very old, deep, overgrown with trees	...	...	...	...	...	...	...
168	660	*Willey Heath Brickfield. Chalk exposed under clay-with-flints, which occurs in numerous pipes so close together as to be only separated by pinnacles of chalk. *H. planus* and *Pentacrinus* found. For fossils see p. 215...	...	...	...	D.	...	...	...

169	550	*Opposite Gasworks, Caterham Asylum. Now filled up with rubbish					...
170	735	"Gravel" pits at Caterham Waterworks. Large pits in outlier of Blackheath pebble-beds					...

SHEET 26 N.E.—MERSTHAM AND KINGSWOOD DISTRICT.

171	500	*Smugglers' Pit, Hogden Bottom, totally overgrown with trees					...
172	500	*S.W. of Beechen Copse. Old shallow pit overgrown with trees					...
173	500	*In Grub Wood. Full of trees					...
174	520	*On Reigate Road, one-third mile N. of Lower Kingswood Church. Deep pit, full of large trees					...
175	585	On Reigate Road, quarter mile S.E. of Lower Kingswood Church. Gravel pit. ...					...
176	500	*N. of Well House, Hogden Bottom, overgrown with trees					...
177	500	*S. of Well House, Hogden Bottom, overgrown with trees					...
178	500	*In Longcroft Shaw. Old, but large exposure, fossils scarce, chalk massive				F.	...
179	500	*Quarter mile E. of Mugswell. Very old and full of trees. A little chalk exposed, very few fossils					...
180	500	*Quarter mile W. of Prior's Field School, overgrown with trees					...
181	440–480	In Markedge Lane, Gatton. Small quarry still in use, on S. side of escarpment in a small obsequent coombe. The lower part, about 7 ft., is in Grey Chalk, mostly covered with talus, and with no fossils worth recording. The upper 30 ft. is in *R. cuvieri*-zone, and the usual fossils are fairly plentiful. One fine example of *Ammonites peramplus* (20 in. diam.)	A.	B.			...
182	500	*Quarter mile N. of Coldroast Farm. Overgrown with trees					...
183	530	*Quarter mile S.W. of Coldroast Farm. Overgrown with trees					...
184	560	*At Furzefield Shaw, Ashtead Hill. Obscured by trees and talus					...
185	400	At Marling Glen, Merstham. Very old deep pit, covered by talus					...
186	430	Yew Tree Pit, corner of Chipstead Church lane and Brighton Road. Very old, shallow but long pit planted with a double row of yew trees. Small exposure with scattered flints			E.		...
187	500	*N. of Netherne Wood					...
188	530	*S. of Netherne Wood					...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a. zone. F	M. zone. U.M.
		SHEET 26 N.W.—HEADLEY AND WALTON HEATH							
189	500	In Clay Lane, W. of Oyster Hill, Headley. A large pit about 30 ft. deep, in good condition for working, close to Tertiary outlier. Massive blocky chalk, well bedded, flints few. One persistent thin horizontal tabular flint band with layer of yellow chalk just beneath it with numerous fossils. Fossils throughout plentiful and well preserved. For list see p. 215. The whole is in *Marsupites*-band	...	...	...	...	...	...	M.
190	550	250 yards S.W. of Headley Church Full of trees, no exposure	...	...	...	...	...	...	...
191	530	*In Hurst Road, Walton-on-the-Hill. Much overgrown, but with a small exposure	...	...	...	...	...	F.	...
192	540	*In Epsom Lane, 300 yards N.W. of No 191. Very small and badly weathered	...	...	...	...	...	...	...
193	525	*300 yards W. of Dowding Castle. Very old, partly enclosed as orchard. Near Tertiary outlier of Walton-on-the-Hill and at the head of Pleistocene valley of Hogden Bottom	...	...	...	...	...	...	...
194	500	*Hogden Bottom Pit, near Kingswood School. Small pit capped by brickearth with Pleistocene fossils. Nodular flint bands, chalk very white with conchoidal fracture. Now enlarged and Pleistocene nearly all cut away (May, 1905). For fossils see p. 215	...	...	...	...	...	F.	...
195	570	*W. of Reigate Road, 1 mile S. of No. 194. Inaccessible, in centre of thick larch wood	...	...	...	...	...	...	...
		SHEET 25 N.E.—MICKLEHAM DISTRICT. (*Nos.* 196, 197, 198 *W. of R. Mole.*)							
199	175	Behind Mickleham Rectory, overgrown, full of trees	...	...	...	...	...	...	...
200	275	In Highland Park, overgrown, full of trees	...	...	...	...	...	...	...
201	370	Near Highlands Farm, overgrown, full of trees	...	...	...	...	...	...	...
		SHEET 25 S.E.—BOX HILL DISTRICT. (*Nos.* 202 *to* 206 *W. of R. Mole*)							
207	200	N. of Burford Bridge Hotel	...	...	...	...	...	...	...
208	500	*Near Swiss Cottage, Box Hill	...	...	...	...	...	...	...

209	585	*Boxhurst Pit, in Box Hill Road, about 50 ft. below top of Box Hill, overlooking Deepdene. Small but interesting. Junction of H. p. and T. g. zones. *T. gracilis* numerous. *H. planus* and *M. leskei* also found. For fossils see p. 215			C.	D.			...
210	700	*On Brockham Hill, overgrown with trees							...
211	400	In White Road, S. of Duke's Plantation							...
		SHEET 26 S.W.—BETCHWORTH DISTRICT.							
212	400–550	Brockham Lime Works. See "Memoir," vol. ii, p. 55	A.						...
213	400–575	Betchworth Lime Works. See "Memoir," vol. ii, pp. 55, 386, 387	A.	B.	C.				...
214	400–500	Buckland Lime Works ...							...
215	600	At Round Wood...							...
216	480	At Colley Hill, near Reigate ...							...
217	400–500	Colley Pits							...
		SHEET 26 S.E.							
218	700	*At Margery Hall Farm ...							...
219	720	*Quarter mile S.W. of No. 218. Large pit in thick wood, overgrown							...
220	740	*One-sixth mile S.E. of No. 219. Small and shallow, overgrown ...							...
221	400	On Colley Hill, W. of Reigate Hill ...							...
222	500–600	On Colley Hill, one-sixth mile E. of No. 221. Large, bare and rubbly, in escarpment...							...
223	500–700	Farrington's Pits, Reigate Hill. Very large. See "Memoir," vol. ii, pp. 55, 385	A.	B.		...	...	...	...
224	400	In Beech Road, S. of No. 223 ...				...	...	...	...
225	740	*E. of Margery Hall. In thick wood, overgrown				...	...	...	...
226	685	*Blackhorse Pit, at top of Reigate Hill. Small exposure, no fossils				...	...	...	...
227	500–600	Old Pits between Reigate Hill and Wray Lane. Rubbly talus only				...	...	...	...
228	550	In Gatton Park, in Wray Lane, near No. 227				...	...	...	...

No.	Height above O. D.	DESCRIPTION.	Grey Chalk. A	R. c. zone. B	T. g. zone. C	H. p. zone. D	M. c-t. zone. E	M. c-a zone. F	M. zon U.M.
229	500–550	In Gatton Park, N.W. corner of Nut Wood	...	...	...	...	...	...	...
230	400	In Gatton Park, near The Burpit	...	...	...	...	...	...	...
231	450	In Gatton Park, S. of Nutwood Lodge	...	...	...	...	...	...	...
232	280	In Battlebridge Lane, S. Merstham. Not chalk but Lower Greensand	...	...	...	...	...	...	...
		SHEET 27 S.W.—BLETCHINGLEY DISTRICT.							
233	700	At War Coppice	...	...	...	...	...	...	...
234	600	S. of Gravelly Hill. Very deep, full of large trees	...	...	...	...	...	...	...
235	700	S. of Gravelly Hill, quarter mile E. of No. 234. Old. Fossils very scarce (on talus only)	...	...	?	...	...	...	...
		SHEET 27 S.E.—GODSTONE AND OXTED.							
236	600	Nixon's Pit, S.W. of Hanging Wood	...	...	...	...	...	...	...
237	600	At top of Tandridge Hill Lane...	...	...	...	...	...	...	...

LIST OF FOSSILS FROM CERTAIN SELECTED PITS.

	Public Hall, Caterham.	Whyteleafe.	Bozhurst.	Willey Heath.	Chipstead, South Cutting.	Wootton.	Tithe Pit.	Hogden Bottom.	Medical College.	Banstead Cutting.	Russell Hill.	Clay Lane, Headley.
Number of Pit ...	139	119	209	168	84	122A	118	194	49	38. 39	28	189
Zone	*R. c.*	*H. p.* *T. g.*	*H. p.* *T. g.*	*H. p.*	*M. c-t.* *H. p.*	*M. c-t.*	*M. c-a.* *M. c-t.*	*M. c-a.*	*M. t.* *M. c-a.*	*M. t.* *M. c-a.*	*M. t.*	*M. t.*
Siphonia königi	...	...	...	...	...	...	...	...	...	×	...	...
Plinthosella squamata	...	×	×	...	...	...	...	...	×	...	×	×
Ventriculites impressus	...	...	...	...	×	×	...	...	...	...	×	...
Pharetospongia strahani	...	...	...	...	...	...	...	...	...	×	...	...
Porosphæra globularis	...	...	...	...	×	...	×	...	×	×	×	×
Porosphæra nuciformis	...	...	...	...	...	...	...	...	×	...	×	...
Porosphæra pileolus	...	...	...	...	...	...	...	...	×	...	×	...
Porosphæra patelliformis	...	...	...	...	...	...	...	×	...	...	...	...
Porosphæra arrecta	...	...	...	...	...	...	...	...	...	...	×	...
Hydrozoa	...	...	...	...	×	...	×	...	...	...	...	...
Spinopora dixoni	...	...	...	...	...	...	...	...	×	...	×	...
Hydractinia	...	...	...	...	×	...	×	...	...	...	...	...
Coral	...	...	...	×	...	...	...	...	...	...	...	×
Parasmilia centralis	...	×	...	...	...	...	...	...	...	...	×	...
Bourgueticrinus	...	...	...	...	...	...	...	...	×	×	×	...
Bourgueticrinus nipple head	...	...	...	...	...	...	...	...	×	×	×	...
Pentacrinus	...	...	...	×	...	...	...	...	...	...	...	...
Marsupites testudinarius	...	...	...	...	...	...	...	...	...	...	×	×
Uintacrinus	...	...	...	...	...	...	...	...	×	×	×	...
Asteroidea	...	...	...	...	...	...	×	...	×	×	×	×

	Public Hall, Caterham.	Whyteleafe.	Boxhurst.	Willey Heath.	Chipstead, South Cutting.	Wootton.	Tithe Pit.	Hogden Bottom.	Medical College.	Banstead Cutting.	Russell Hill.	Clay Lane, Headley.
Number of Pit ...	139	119	209	168	84	122A	118	194	49	38, 39	28	189
Zone	*R. c.*	*H. p.* *T. g.*	*H. p.* *T. g.*	*H. p.*	*M. c-t.* *H. p.*	*M. c-t.*	*M. c-a.* *M. c-t.*	*M. c-a.*	*M. t.* *M. c-a.*	*M. t.* *M. c-a.*	*M. t.*	*M. t.*
Cidaris sceptrifera	...	...	...	...	×	×	...	...	×	...	×	...
Cidaris clavigera	...	...	...	?	...	...	×	×	...	×	...	...
Cidaris perornata	...	...	...	...	...	...	×	×	...	...	...	...
Cidaris hirudo	...	...	...	...	...	...	...	...	×	×	×	×
Cyphosoma königi	...	...	...	...	...	...	...	...	...	×	×	...
Cyphosoma corallare	...	...	...	...	...	...	...	×	...	...	...	...
Cyphosoma radiatum	...	×	...	...	×	...	...	...	...	...	...	...
Salenia geometrica	...	...	...	...	...	...	...	...	...	×	...	...
Echinocorys vulgaris (sub-*pyramidatus*)	...	...	...	...	...	...	...	...	×	×	×	×
Echinocorys vulgaris (tall dome)	...	...	...	...	...	...	...	...	...	×	×	×
Echinocorys vulgaris (large dome)	...	...	...	...	...	...	×	×	...	×	...	...
Echinocorys vulgaris (gibbous)	...	...	...	...	×	×	×	...	...	...	...	...
Echinoconus conicus	...	...	...	...	...	...	...	×	×	×	×	...
Echinoconus conicus, var. *tumidus*	...	...	...	...	...	...	...	×	...	×	×	...
Echinoconus sub-rotundus	×	×	...	...	...	...	...	...	...	...	...	...
Discoidea dixoni	×	...	...	...	...	...	...	...	...	...	...	...
Micraster cor-anguinum	...	...	...	...	...	...	...	×	×	×	...	×
Micraster cor-anguinum, var. *rostratus*	...	...	...	...	...	...	...	...	...	...	×	×
Micraster præcursor, M. c-a. type	...	...	...	...	...	...	×	...	...	...	...	...
Micraster præcursor, M. c-t. type	...	...	...	...	×	×	×	...	...	...	...	...
Micraster præcursor, ditto, var. *cor-testudinarium*	...	...	...	...	×	...	×	...	...	...	...	...
Micraster præcursor, H. p. type	...	...	...	...	×	...	...	...	...	...	...	...

Micraster leskei ...	...	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...
Micraster cor-bovis	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...
Hemiaster minimus	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...	...
Holaster planus ...	...	...	...	...	...	...	×	×	...	...	...	...	...	...	...	...
Holaster placenta ...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...
Serpula sp. ...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...
Serpula ampullacea	...	...	...	...	...	...	...	...	×	×	×	...	...	...	...	...
Serpula fluctuata ...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Serpula gordialis ...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...
Serpula ilium ...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Serpula macropus ...	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Serpula plana ...	...	...	...	...	...	...	...	...	×	×	×	...	...	...	...	×
Serpula plexus ...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...
Serpula turbinella...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	...
Terebella	...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...
Bryozoa	...	...	...	...	...	×	...	...	...	...	...	×	...	...	...	...
Stomatopora sp. ...	...	...	...	...	...	...	...	...	×	...	...	...	×	×	×	...
Stomatopora granulata	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	×
Stomatopora gracilis	...	...	...	...	...	...	...	...	×	×	×	...	...	...	...	×
Stomatopora spicea	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Stomatopora ramea	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	...
Proboscina ramosa	...	...	...	...	...	...	...	...	×	×	×	...	...	...	...	...
Proboscina cornucopiæ	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...
Proboscina anomala	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Proboscina elevata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Proboscina dilatata	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×
Berenicea sp. ...	...	...	...	...	...	...	...	...	×	...	...	...	×	×	...	...
Berenicea gracilis...	...	...	...	...	...	...	...	...	×	...	×	...	...	...	...	...
Berenicea phlyctænosa	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...
Berenicea papillosa	...	...	...	...	...	...	...	...	...	×	×	...	...	...	...	...
Berenicea regularis	...	...	...	...	...	...	...	...	×	...	...	...	...	...	...	×
Idmonea alipes ...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	×
Idmonea cristata ...	...	...	...	...	...	...	...	...	...	...	×	...	...	...	...	...
Membranipora ...	...	...	...	...	...	...	...	...	×	...	×	...	×	×	×	...

	Public Hall, Caterham.	Whyteleafe.	Boxhurst.	Willey Heath.	Chipstead, South Cutting.	Wootton.	Tithe Pit.	Hogden Bottom.	Medical College.	Banstead Cutting.	Russell Hill.	Clay Lane, Headley.
Number of Pit ...	139	119	209	168	84	122A	118	194	49	38. 39	28	189
Zone	*R. c.*	*H. p.* *T. g.*	*H. p.* *T. g.*	*H. p.*	*M. c-t.* *H. p.*	*M. c-t.*	*M. c-a.* *M. c-t.*	*M. c-a.*	*M. t.* *M. c-a.*	*M. t.* *M. c-a.*	*M. t.*	*M. t.*
Homolostega ...	...	...	...	...	×	...	×	...	...	...	...	...
Eschara rimosa ...	...	...	...	...	...	...	...	...	...	×	...	×
Actinopora disticha ...	...	...	...	...	...	...	...	...	...	...	...	×
Actinopora complanata ...	...	...	...	...	...	...	×	...	...	...	...	...
Crania egnabergensis ...	...	...	...	...	×	...	...	...	...	...	...	...
Thecidea wetherelli ...	...	...	...	...	...	...	...	...	...	×	..	×
Kingena lima ...	...	...	...	...	...	...	...	...	...	×	...	..
Terebratulina striata ...	×	...	...	...	...	...	×	...	...	...	×	...
Terebratulina gracilis ...	...	×	×	×	...	...	...	...	...	...	...	...
Terebratula semiglobosa ...	×	×	...	×	×	×	×	×	...	...	...	...
Terebratula carnea ...	...	×	×	...	×	×	×	...	...	...	...	...
Rhynchonella limbata ...	...	...	...	...	×	×	×	...	...	...	...	...
Rhynchonella reedensis ...	...	...	...	×	...	...	×	×	...	×	...	...
Rhynchonella cuvieri ...	×	...	×	×	...	...	...	...	...	...	...	...
Rhynchonella plicatilis ...	×	...	...	×	...	...	×	...	...	×	×	...
Janira quinquecostatus ...	...	×	×	...	...	...	×	...	×	...	×	...
Spondylus spinosus ...	...	×	×	×	×	...	...	×	×	×	×	...
Spondylus dutempleanus ...	...	...	...	...	...	×	...	...	?	...	...	...


126
122A
127
153
213
Y
Barn
793
777
Quarry F
Inn
Smithy
Common
Newhouse Fm

)F TS.

nch

Ostræa sp. ...	...	...	...	...	...	...	...	×	...	×	...	...	×	×	...	×
Ostræa vesicularis	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...
Ostræa hippopodium	...	...	...	...	...	×	×	...	×	...	...	...	...	×	...	...
Ostræa wegmanniana	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...
Ostræa lateralis ...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	×	...
Plicatula sigillina ...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	...	...
Inoceramus sp. ...	...	...	...	...	...	...	...	...	...	...	×	...	...	×	×	×
Inoceramus mytiloides	...	...	...	...	×	×	...	...	...	...	...	...	...	...	...	...
Actinocamax granulatus	...	...	...	...	...	...	...	...	...	...	...	...	×	...	?	×
Antinocamax verus	...	...	...	...	...	...	...	...	...	...	...	...	×	...	×	...
Scalpellum maximum	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...
Fish scales ...	...	...	...	...	...	...	...	...	...	×	×	×	×	...	×	...
Sharks' teeth ...	...	...	...	...	...	...	...	...	...	...	...	...	...	×	...	...
Enchodus	...	...	...	...	...	×	...	...	...	...	...	...	...	...	...	...
Corax falcatus ...	...	...	...	...	...	×	...	×	...	...	...	...	...	...	...	...

EXCURSION TO REDHILL, WOODHATCH, AND REIGATE.

SATURDAY, JUNE 24TH, 1905.

Director: W. P. D. STEBBING, F.G.S.

Excursion Secretary: G. W. YOUNG.

(*Report by* THE EXCURSION SECRETARY.)

ON arriving at Redhill station the party, numbering about 30, after having had their attention called to the position of the Sandgate Beds, ascended Redstone Hill and proceeded to Hooley Sand Pit, near Earlswood, which shows a fine section of the Hythe beds of the Lower Greensand, locally known as Redhill Sand. The Director pointed out some small but interesting step faults, rendered noticeable by the displacement of some thin seams of ferruginous sandstone, and accounted for by a slight movement of the hill to the south over the Atherfield Clay.

On the way to Earlswood Common a small brickfield in the Weald Clay was visited where some dry lumps of shaly clay yielded *Cypris*, which was the only fossil found. Earlswood Common consists of Weald Clay with occasional ridges due to the presence of bands of Paludina Limestone or "Wealden Marble." The members were soon busy with their hammers among the loose pieces of stone, and some satisfactory specimens were obtained.

The party then walked westward to Mr. John Brown's brickfield in the Atherfield Clay at Woodhatch. The section here is probably the best to be seen in this formation in this part of England, and has already yielded upwards of forty characteristic species of the period. In the lower part fossiliferous Doggers occur, from which a characteristic fauna was obtained, including *Perna mulleti*, *Exogyra sinuata*, *Ostræa*, *Pinna*, *Gervillia*, *Pecten*, *Scalaria*, etc.

Tea was obtained in Reigate, after which a few enthusiasts completed the programme by visiting a pit close to the railway, west of the station, and were rewarded by seeing a fine section of the Folkestone Sands showing a junction with the Gault in the north-west corner. At this point the sands were seen to become clayey and darker in colour before reaching the actual junction, which showed a dark grey sandy clay about one foot thick, full of nodules of a whitish colour. Mr. Whitaker remarked that when he mapped the district, many years before, the pit was much smaller and did not show the junction.

A vote of thanks to the Director closed the proceedings, and the party returned to town by the 8.33 train from Reigate.

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EXCURSION TO BISHOP'S STORTFORD AND STANSTED.

July 15th, 1905.

Director: The Rev. A. Irving, D.Sc., B.A., and Mr. Percy A. Irving.

Excursion Secretary: T. W. Reader, F.G.S.

The party left Liverpool Street (G.E.R.) by the 1.23 p.m. train and arrived at Stansted at 2.40 p.m. They were met by the Directors and proceeded to the old Chalk pit at the Castle Hill, where a fault was seen which had equally affected the Chalk, the Reading Beds, and the overlying gravels. The downthrow of about 6 ft. was to the north. The large gravel pits close to the station were next visited. Here, at 225 ft. O.D., from 30 to 40 ft. of gravels and boulder drift of the valley were exposed. The section in the station pit taken transversely to the line of the valley gives at the present time the following succession:—

	ft.
(*c*) Boulder Clay, including subordinated zones of feebly-stratified silty matter	10
(*b*) Glacial boulder detritus, almost made up of flint boulders and some angular blocks, with occasional boulders of palæozoic and mesozoic rock material	10
(*a*) Stratified gravel with a slight 'horse-back' arrangement, containing much small rolled chalk detritus, along with triassic and other débris from the older rocks	15

Dr. Irving stated that in this section, two remarks were admissible :

(1) A large proportion of the flint boulders (*b*) must, from their weathered appearance, have undergone long exposure at the surface before their accumulation here, even as the flints picked off the land and built along with palæozoic boulders into numerous walls of churches, etc., all over this side of England show signs of exposure.

(2) The abundance of small chalk pebbles in the lowest deposit (*a*), may be taken to indicate the stage of the fluviatile erosion of the ancient Mercian region in Tertiary times at which the attenuated cretaceous strata, extending then far beyond the present Chalk escarpment, were being sawn through.*

Leaving these interesting and instructive sections, the party proceeded to a Chalk pit near Brooklands, where a junction between the Chalk and Tertiaries was seen. At Foxdells a section was seen showing "Rubble" overlain by coarse material containing blocks of older rocks than the Chalk, and by a well-stratified gravel containing much finer Chalk detritus. Rolled fragments of granite, of several basic crystalline rocks, Carboniferous limestone and various quartzites were obtained here. The proprietor of the pit, Mr. John Barker, J.P., then welcomed the party to his residence, The Grange, and provided welcome hospitality.

As the party proceeded in the drag along the Cambridge Road towards Stortford, the Director pointed out that the high ground of Birchanger to the east was capped by London Clay, of which bricks were made. The sections are now obscure, but they formerly yielded sharks' teeth, septaria, etc. The base of the formation was marked by a band of black flint pebbles and oysters, where the sands of the Reading series below were dug out.

At Mr. J. Day's brickworks, Rye Street, Bishop's Stortford, the clunchy character of the bed reposing immediately upon the Chalk, with green-coated flints (as at Reading), was pointed out by the Director. A number of specimens of *Micraster cor-anguinum* have during the past few years been obtained from this pit.

A drive through the town to the gravel pits on the Hallingbury Road, that belonging to Sir Walter Gilbey, on the Hockerill Park Estate, and the much more extensive one belonging to the Urban District Council were visited. From the former of these the "shingle" newly laid down at Hockerill Vicarage was obtained, full of triassic rolled débris. The larger pit was more closely inspected, where the well-stratified gravels were seen passing up into stratified gravelly sands, the whole capped with Boulder Clay. These constitute the terrain of the high ground of Hockerill Park Estate, the Director mentioning that recent excavations for building and deep sewers (in one case 18 ft. deep) had proved the powerful development of the very chalky Boulder Clay in that

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* *Cf.* A Ramsay, "Physical Geology and Geography of Great Britain," Fig. 29, (p. 313, Ed. 5); also the recent work of Dr. A. E. Salter, F.G.S., in *Proc. Geol. Assoc.*, vol. xix, pp. 1 *et seq.*

locality, with large angular blocks of palæozoic and mesozoic rocks, as well as flints from the Chalk. The two pits on the Thorley side of the valley represent the gravels in their most ancient character, extremely indurated with layers conglomerated by carbonate of iron, in both cases overlain also by the Boulder Clay of the district, here with very little chalky stuff in it, though a little farther to the north, near the cemetery, it again takes on the chalky character. A pretty full account of the larger and older pit, that belonging to Mr. Laurie Frere, was given in 1897; but the new pit opened by the London Road since that time is of exceptional interest. A certain transverse quaquaversal arrangement of the stratification of the gravels was observed in the older and larger pit as it was worked; but in the smaller and newer pit a little to the north that arrangement is very striking; as is also the marked unconformity, the shingle-bank having had its ridge planed off before the Boulder Clay was dropped upon it.

In the 1897 paper there is given a list of ten well-sections at Bishop's Stortford, in which the Chalk was reached at depths below the present alluvial plain of the valley varying from 50 to 170 ft., the details of the deepest being given according to the account furnished by the well-sinker, Mr. Ingold. More definite information is now in the writer's possession from a section at another well at the Anchor Maltings, recently sunk by his successor, Mr. Featherby, who accompanied the party on July 15th. The specimens were arranged for inspection with a sectional drawing to scale of the well, by Mr Percy Irving. The succession is as follows:—

	ft.
1. Angular flinty gravel well washed	13
2. Chalky sand and fine gravel	5
3. The same, but coarser	27
4. The same, but more irony	15
5. Fine silt, hardening on drying	5
6. The same, with fine chalk-gravel	30
7. The same, of coarser sand	20
8. Coarse gravel of flint and Chalk	8
9. Chalk rubble containing small flints	2
To the Chalk rock	125
Chalk pierced to	187
Total depth of well	312

All the specimens 2 to 9 are highly calcareous. The question left open in 1897 as to the possible identity of these well-sectioned deposits in the Stort alluvium with the Stansted gravels is now answered decidedly in the negative; and the diagnosis of the buried valley and its contents would appear to be pretty complete. Further details, as they come to hand, may necessitate slight modifications in its reading here and there, but are not likely to invalidate the history of the valley which data at present to hand have enabled us to construct, as that of an ancient *Tertiary valley of a great affluent of the Lower Thames-Rhine estuary*, its inception, dating back at least to Miocene times, more or less obliterated since, during the Glacial Period, and by recent alluvial deposits, while at Stansted and a little farther down the amount of post-glacial work of erosion done by the present stream can be observed.

The day wound up with tea at Hockerill Vicarage, together with a study of well-sections along with a great variety of rock-material collected from the Boulder Clay of the Herts and Essex border by Mr. Percy Irving, and a collection of specimens obtained by the same from the base of the Bunter Sandstone near Mansfield, Notts, for comparison with the triassic débris found in the gravels and the Boulder Clay.

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EXCURSION TO THE BERKSHIRE DOWNS.

SATURDAY, JULY 22ND, 1905.

Directors: H. J. OSBORNE WHITE, F.G.S., AND
LLEWELLYN TREACHER, F.G.S.

Excursion Secretary: W. P. D. STEBBING, F.G.S.

(*Report by* LL. TREACHER.)

THE party arrived at Newbury about 10.30, and were met at the station by Mr. Frank Comyns, M.A. who led the way to the Museum, of which he is the Hon. Curator. Here they were joined by several local residents, and Mr. Comyns related the circumstances connected with the restoration of the Old Cloth Hall and its adaptation to the purpose of a Museum, and gave a brief description of the principal contents. The shortness of the time at their disposal prevented the members making more than a somewhat hasty inspection of the collections, but they especially noticed a fine skull, with horn-cores intact, of *Bos primigenius* from the peat of the Kennet Valley, teeth of the same and of other animals, horns of red deer and roebuck, nuts, etc., from the same deposit, two large neolithic flint celts from the peat, implements of bronze from local barrows, and some good specimens of ancient pottery found in, and near, Newbury. Also a small but interesting collection of local chalk fossils, presented by Miss M. Baylis, of Boxford, attracted some attention.

Mr. H. B. Woodward, F.R.S., in proposing a vote of thanks to Mr. Comyns, referred to Professor Rupert Jones, the oldest living geologist, and his early connection with Newbury, as the author of several papers on the geology of the district, and also as the collector of many of the specimens now in the Museum.

The party then left for the station, where they took the 11.45 train for Lambourn. During a stroll through the ancient town the extensive use which had been made of the local Sarsens as building material was noticed, some very large specimens also forming the south wall of the churchyard. Entering the carriages here the road was taken northward towards Ashdown Park. On the way a short stop was made at Fognam Barn to examine a small quarry in the *Terebratulina*-Zone, which they were informed had been opened to procure chalk for building, and a wall close by showed that it had served the purpose very well. The only fossils found were *Terebratula semiglobosa* and a small *Ostrea*.

Passing on, many Sarsens were noticed strewed over the bottom of the valley, both in and outside the park. At one point the members left the carriages to make a closer inspection of some of the stones, and Mr. White gave a brief resumé of the various theories which had been advanced to account for their origin and present position. In his opinion the balance of evidence seemed to be slightly in favour of their being of the age of the Reading Beds. Angular fragments of flint occur in some of the Sarsens, as was seen in the wall of a house in Lambourn, but none were observed in the Ashdown specimens.

The main road was then left for a grass track leading to Wayland Smith's cave, a chambered cromlech built of Sarsens. It is situated in a small plantation on the north side of the Ridgeway. There was no evidence forthcoming as to the age of the structure, but on the surface of the fields close by Mr. A. S. Kennard found several worked flints, including one good scraper. After a discussion, chiefly of an archæological and legendary character, the party proceeded eastward along the Ridgeway to Uffington Castle, a large prehistoric earthwork occupying a prominent position at the northern end of a ridge of Upper Chalk, which stands up above the plain of Middle Chalk, and has a well-marked secondary escarpment facing the west.

Walking across the "Castle" the members gathered on the northern slope to listen to a description by the Directors of the fine panoramic view spread out before them. Looking northward the Cotswold Hills could be distinguished through the faint haze which prevailed on the horizon. In the middle distance the ridge of the Corallian rocks between Highworth and Faringdon was well seen and Faringdon Clump, an outlier of Lower Greensand, was a very conspicuous object in the landscape. Coming closer, the floor of the Vale of White Horse, composed of Kimeridge Clay, Gault, and Upper Greensand, reached nearly up to the Chalk escarpment on which they were standing. Owing to the fact that they were looking up the dip-slope of the various strata the country had the somewhat deceptive appearance of being nearly a level plain. The courses of the longitudinal valleys of the rivers Ock and Upper Thames were pointed out. The positions of some of the springs at the foot of the escarpment and the manner in which they were cutting it back were noted. The White Horse Hill appeared to be attacked by a pair of springs, the one on the west rising below the depression known as the Manger, the Dragon Hill projecting between the two. The comparative scarcity of woodlands over the Vale was observed, the principal trees being those in the boundary fences of the fields. The cause of this was probably that the great fertility of the soil did not allow of much land being used for woods. The figure of the White Horse was then inspected, and likened to that of an attenuated cat, and the various legends relating to the spot passed in review, after which the carriages were again taken for a rapid drive along the grassy Ridgeway to the top of Blowing Stone Hill. From here the members walked down to examine the famous Blowing Stone and to try their hands, or rather their lungs, upon it. It is a large Sarsen, honeycombed with tubular borings, and is said to have been brought from the downs above, many years ago. Local tradition gives it the name of King Alfred's bugle horn, as, by blowing into one of the holes, an experienced person can produce a sound something like that of a hooter. On this occasion the members were not particular successful in making the hills resound with its notes, but a local resident was able to convince them of the possibility of doing so.

Having regained the hill-top, an inspection was made of the old chalk quarry by the road-side. The base of this was seen to consist of the Melbourne Rock, which is worked for road-metal. The Belemnite Marls which immediately underlie the rock were not visible. A search for fossils resulted in a few fragments of *Inoceramus* shells and a small shark's tooth.

The party then drove back, via Seven Barrows, to Lambourn for tea. In acknowledging a vote of thanks to the Directors, Mr. White said he was afraid they had not given so much geology as is usually expected on their excursions, the reason being that this excursion had to be rather hurriedly arranged in place of one proposed to Savernake which had to be abandoned at the last moment, owing to unexpected difficulties with the proprietors of a brickyard there. The members left Lambourn by the 6 o'clock train.

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LONG EXCURSION TO CENTRAL WALES.

JULY 24TH, to JULY 29TH, 1905.

Directors: THE PRESIDENT, PROF. W. W. WATTS, M.A., F.R.S., HERBERT LAPWORTH, F.G.S., AND MISS GERTRUDE L. ELLES.

(*Report by* THE DIRECTORS.)

LLANDRINDOD WELLS was fixed on as the headquarters of the Excursion, and the party stayed at the Brynawel Hotel, where part of the Members assembled on Saturday, the 22nd, their full strength being about 45. On Sunday afternoon the President led a walk over the hill to Cefn Llys, getting a good general view of the country and seeing the exposure of volcanic ash and other igneous rocks.

Monday, July 24th.

The object of the day's work was the study of the zonal succession of the Wenlock Shales and their relation to the underlying rocks. With this end in view the party left Llandrindod shortly after 9.30 and drove along the Builth Road till Dulas Brook was reached, where a halt was made to examine the Wenlock Shales (Zone of *Cyrtog. rigidus*) exposed in the banks of that stream. Many specimens of *Monog. Flemingii* var. *y.* and *M. dubius* were obtained, together with a few examples of the zone fossil.

Continuing a short distance farther along the road Coed Mawr quarry was next visited, and characteristic graptolites were obtained from the beds forming its upper portion (Zone of *Cyrtog. Linnarssoni*), while it was noted that the beds exposed on the floor of the quarry yielded a somewhat different fauna (Zone of *Cyrt. symmetricus*).

The party then proceeded up the side road to Trecoed, where the relationship of basal beds of the Wenlock Shale (Zone of *Cyrtog. Murchisoni*) to the underlying Llandovery Grit and Llandeilo Flags was clearly seen. The basal beds of the Wenlock Shales consist of hard calcareous flags, and yielded *Cyrtog. Murchisoni*, *Monograptus vomerinus*, *M. priodon*, while a few small brachiopoda and specimens of *Acidaspis Prevosti* were also found. These beds were seen to rest unconformably upon the Llandovery Grit (= Sedgwickii Grits of Rhayader District), which in its turn was seen resting unconformably upon Llandeilo Flags containing *Ogygia Buchii*, etc.

Returning to the carriages at Castle Crab, the party proceeded to Pencerrig (driving through the grounds by kind permission of Miss Thomas) to examine the famous section in the Llandeilo beds seen behind the house. Attention was called to the alteration effected by a sill of dolerite, and the descent was then made to the stream flowing from Pencerrig, in order to examine the section in the zone of *Cyrtog. Murchisoni* and the best locality for Wenlock Shale fossils in the district. Numerous magnificent specimens of the zone fossil and its associates were procured. A few members also examined again the Llandovery Grit seen close to the lake. Passing through the woods and entering the grounds of Wellfield House (by courtesy of D. Thomas, Esq.), the well-known Harper's Quarry was next visited, and the alteration effected by the sill of dolerite on its northern face observed and commented on. The party were then conducted to Wellfield House, from the terrace of which a most excellent view of the country lying to the south was obtained, and attention was called to the main geological features affecting the scenery. After partaking of tea in Builth, a drive was taken eastwards to Cinthio saw-mills, where the members of the Association had an opportunity of studying the highest beds of the Wenlock Shale, which are believed to have overlapped all the lower members of the series at this point, and to rest directly upon the Llandeilo Beds.

During the return journey visits were paid to several quarries in the Igneous Rocks associated with the Llandeilo Flags.

These rocks consisted of interbedded volcanic tuffs, in which a few fossils were found, a coarse agglomerate, and andesites, diabase-porphyrites, and diabases, all of which are regarded by Mr. H. Woods as probably intrusive. No evidence as to the date of intrusion was seen.

Tuesday July 25th.

The object of the day's work was the further study of the Wenlock Shales and their relation to the beds above and below them. Leaving Llandrindod by 9.14 train for Builth Road, the party at once left the station and proceeded to the examination of the good section seen in the roadside close at hand (Zone of *Cyrtog. linnarssoni*). Walking thence to Grove Cottages the beds belonging to the zone of *M. riccartonensis* were studied and numerous examples of the zone-fossil and *M. capillaceus* were obtained.

The party thence proceeded to Gwern-yfid-fach Quarry, where the Llandeilo Flags are very fossiliferous, and where numerous trilobites, *Barrandia* sp., *Ogygia Buchii*, *Trinucleus fimbriatus*, were associated with *Coenograptus (Nemag) gracilis*, *N. explanatus* and *Dicellog. sextans*.

The members of the Association then descended to the bed of the River Wye, which they crossed, and examined the section exposed along its banks between the Railway Bridge and Builth.

The Wenlock Shales were seen resting upon the Llandovery beds, which are here calcareous and full of fossils (*Pentamerus oblongus*, etc.). Immediately underlying them are the Llandeilo beds and their associated volcanic rocks. The alteration of the black Llandeilo Flags into light coloured porcellanite was especially noticed and commented upon.

Passing on to where the River Irfon joins the River Wye the members proceeded some little distance up the Irfon to examine the passage between the Wenlock Shales and the Lower Ludlow Shales. It was observed that there was practically no lithological difference in the beds, the change being a purely palæontological one, and consisting in the replacing of the *Flemingii*-type of graptolite by forms of the *colonus*-type.

Wednesday, July 26th.

The party left Llandrindod in brakes at 9 a.m., and drove viâ Yr Allt and Doldowlod to Cerig Gwynion, where the base of the Lower Llandovery formation is admirably exposed. Here a short account was given of this formation as developed in Britain, with a general description of the same group as developed in the Rhayader District (Gwastaden Group). The members examined the Cerig Gwynion Grits, collected graptolites, and walked for some distance along the Builth Road, working gradually up the succession from the Cerig Gwynion Grits, through the basal flaggy beds, in which *Climacograptus normalis* was obtained, to the Dyffryn Flags, from which several specimens of *Diplograptus modestus* were extracted. From Dyffryn the party were driven to Rhayader, the various exposures in the lower half of the ascending succession being pointed out on the journey. Leaving the brakes at St. Winifred's Church, the members walked to Ddôl Farm to examine the remainder of the Gwastaden Group, as exposed very completely in the banks of the River Wye. Numerous typical graptolites were obtained at various points from the Ddôl Shales up to the *Convolutus* mudstones; including *M. cyphus*, *M. fimbriatus*, *M. communis*, *M. convolutus*, etc.; and at the summit of the *Convolutus* beds the top of the Gwastaden Group with the overlying Rhayader Pale Shales (or Tarannon) was pointed out.

Having seen the unbroken succession through the Lower Llandovery of Rhayader, the party were driven to the foot of the Glyn Hill, at the top of which the Caban or Upper Llandovery formation is exposed. The members then left the brakes, and ascended the steep path to the summit. Here the basal conglomerates of the Caban Group are well exposed, and they were thoroughly examined by the members. The stratigraphical relations, including the unconformity and overlap between the Upper and Lower Llandovery Groups, were explained; and the prominent topographical features of the landscape pointed out. After tea on the summit, the party walked over the hill, through the Upper Bala Group, and down to Doldowlod, where they re-entered the brakes and were driven back to Llandrindod.

Thursday, July 27th.

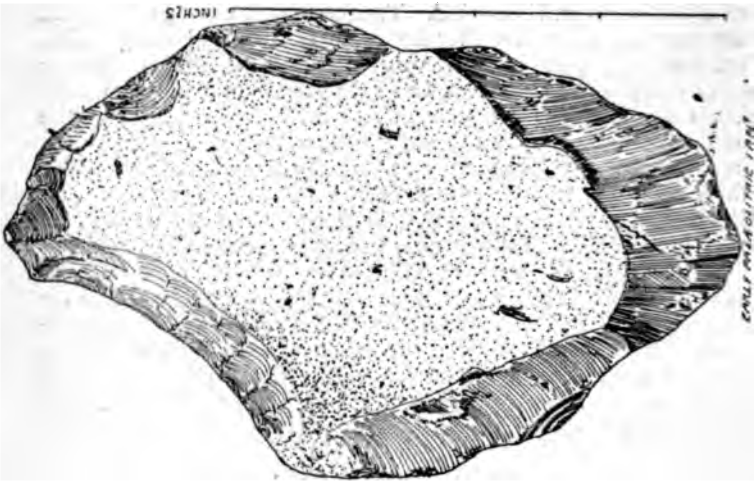
Leaving the hotel at 9 a.m., the members were driven viâ Nantmel and Rhayader to the Birmingham Waterworks in the Elan Valley. At Nantmel Professor Lapworth gave an interesting account of the probable glacial history of some fine exposures of drift on the high road. From Caban Coch, about half a mile east of the dam, the party proceeded on foot along the high road. The various beds of the Caban Group, or Upper Llandovery, on the sides of the road and in the magnificent exposures on the opposite side of the gorge, were pointed out, the group including the Basal Conglomerates, the *Sedgwickii* beds and Gafallt Shales. After passing through this succession the party entered the Gigfran Quarry, where the Lower Conglomerate, which has been used in the building of the masonry dams on the Waterworks, is finely exposed with clean unweathered surfaces. Here an account of the Caban Rocks was given, with a description of the Birmingham Waterworks. The Caban and Dol-y-mynach dams, the village, and various parts of the Works were pointed out and described. After lunch at the quarry, fossils were successfully hunted for; and the members drove up the Elan Valley in order to see the remaining dams and reservoirs, which are now completed. The magnificent scenery passed through was much admired. At Pont-hyllfan the members descended from the brakes and proceeded on foot to Pen-y-Gareg dam. From this point a short walk to the turn of the valley took the party into full view of the remaining portion of the works, including the Craig Goch dam. From Pen-y-Gareg the same route was covered back to Rhayader. Tea was obtained at the Lion Hotel, after which the party were driven back to Llandrindod.

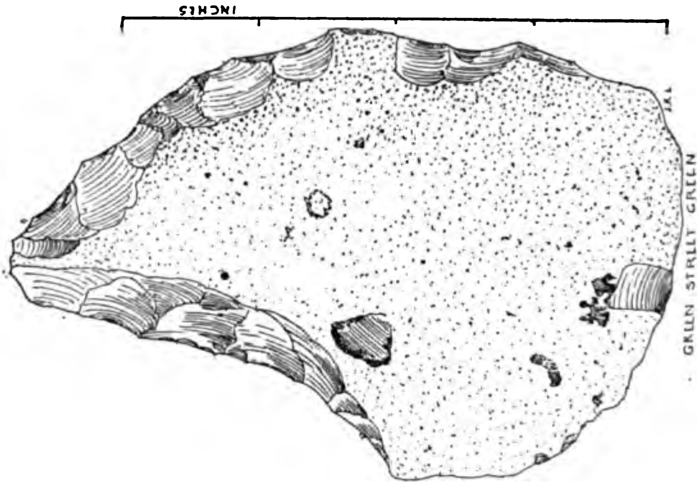
Friday, July 28th.

The party left Llandrindod by special train at 7.30. a.m. joining the Cambrian train at Builth Road, and arriving at Llanidloes at 8.47, where breakfast was prepared at the Trewythen Arms Hotel. Leaving the hotel at 9.30, the members were driven in brakes, via Llangurig and Glansevern Arms, to Steddfa Gurig at the foot of Plynlimmon. Here the members left the brakes, and were joined by a local guide, who conducted them to the summit. On the way the history of the Geology of Mid Wales was given; and the inaccuracy of Keeping's conclusions was demonstrated by the numerous graptolites which were collected in situ and identified. The top of the mountain, 2,469 ft., was reached after a rather hot walk of two and a-half miles, but the party were amply rewarded by the magnificent view in every direction : to the west, Cardigan Bay from the Lleyn Peninsula and Bardsey Island nearly to St. David's Head; to the north, Cader Idris with the outlying mountains round Snowdon, beyond it, the Arenigs; to the east, the rugged mountainous country through which the party had come; and to the south Brecon Beacons and the mountains of Carmarthenshire. After lunch on the top, the hill was descended, and the carriages met again at Steddfa Gurig, whence the same drive was followed back to Llanidloes, the journey being broken at the Glansevern Arms for tea. The party left Llanidloes by the 5.27 train and at Builth Road were taken on by the special to Llandrindod, which was reached at 6.50 p.m. After dinner the usual votes of thanks were given to the Directors and others who had helped in the success of the excursion.

Saturday, July 29th.

A smaller party than that of the previous days left Llandrindod by the 9.14 train for Llandovery, where carriages awaited their arrival. They then drove through the valley of Cwm-y-Dwr as far as Horeb Chapel. Alighting here and ascending the road in the wood beyond the Chapel, the President called attention to the section of typical Old Red Sandstone, dipping at a high angle. Owing to unfavourable weather, a halt was made at the top of the first slope, without proceeding farther for the view, and the President explained that the object of the day's excursion was to compare the Horeb Chapel section with that of the corresponding formations studied at Ludlow in 1904. The high dip caused a great thickness of rock to be observable within a small space. The Lower Old Red Sandstone exhibited scarcely any intermingled cornstone, and diligent search revealed no fossils. Below the red sandstone cropped up a considerable thickness of micaceous flagstones, corresponding with the "tilestones" of Ludlow, and worked in a small quarry in the wood just above Horeb Chapel. Then followed a series of mudstones, shales, and sandstones, with very little calcareous matter, proved by their fossils to be equivalent to the Ludlow and Wenlock formations. The Upper Silurian strata of this district thus differed strikingly from those of the typical Shropshire area in the absence of limestones. The lenticular patches of casts of marine shells, long ago described by Murchison, were well seen in the tilestones, and fossils were next collected at various parts in the road-section. At 1 p.m. some of the party left to catch the 2.5 train for London. The others con-





FIGS. 1 AND 2.—EARLY PALÆOLITHS, CRAY GRAVELS.

tinued, in unsatisfactory weather, to follow the succession of Ludlow and Wenlock rocks as far as the Halfway House. Fine specimens of the Upper Wenlock Graptolites, *Monograptus Flemingii* and *M. colonus*, were found in a quarry in the small valley to the right; while *M. Flemingii* and numerous other fossils were obtained from another quarry behind the Halfway House. From this point the party drove back to Llandovery, and returned to Llandrindod by the 6.35 train.

EXCURSION TO CHELSFIELD AND WELL HILL.

SATURDAY, 2ND SEPTEMBER, 1905.

Director: J. RUSSELL LARKBY.

Excursion Secretary: MR. T. W. READER, F.G.S.

(*Report by* THE DIRECTOR.)

THE members arrived at Knockholt Station at 2.20 p.m., and proceeded along the valley of the Cray. At the railway cutting near the station, attention was drawn to the slight northerly dip —some five degrees—of the chalk, due to the position of the area on the outskirts of the Weald. On the top of the Chalk is a small section of clay-with-flints, deepening at places into pipes; these pipes are filled partly with clay-with-flints, but in one case re-arranged Thanet Sand occurs and thus forms a connecting link between the Thanet Sand of the Well Hill outlier and the Tertiaries at Orpington. The valley gravels of the Cray can be traced about half a mile beyond Knockholt Station, but following the deepening of the valley towards the north the deposit becomes increasingly evident; at Pratt's Bottom it is eight to ten feet in depth, and at Green Street Green it attains a maximum thickness of some twenty-five feet. In all cases the gravels of this stage rest on deeply rutted Chalk surfaces.

The members then inspected the Director's collection of implements illustrating local gravels; the flints were arranged to show the evolution of form from Eolithic to Neolithic times.

The party then ascended the northern slope of the Cray valley to Little Hoglands Bank, where the extent of the Cray gravels can be appreciated. The gravels of the northern side appear in a continuous strip bordering the slope, and contain implements of Eolithic type*. The gravels of the southern side of the valley cap ridges owing to the development of lateral water courses. These gravels probably came from the Tertiary beds crowning the Chalk escarpment at Knockholt and other high land

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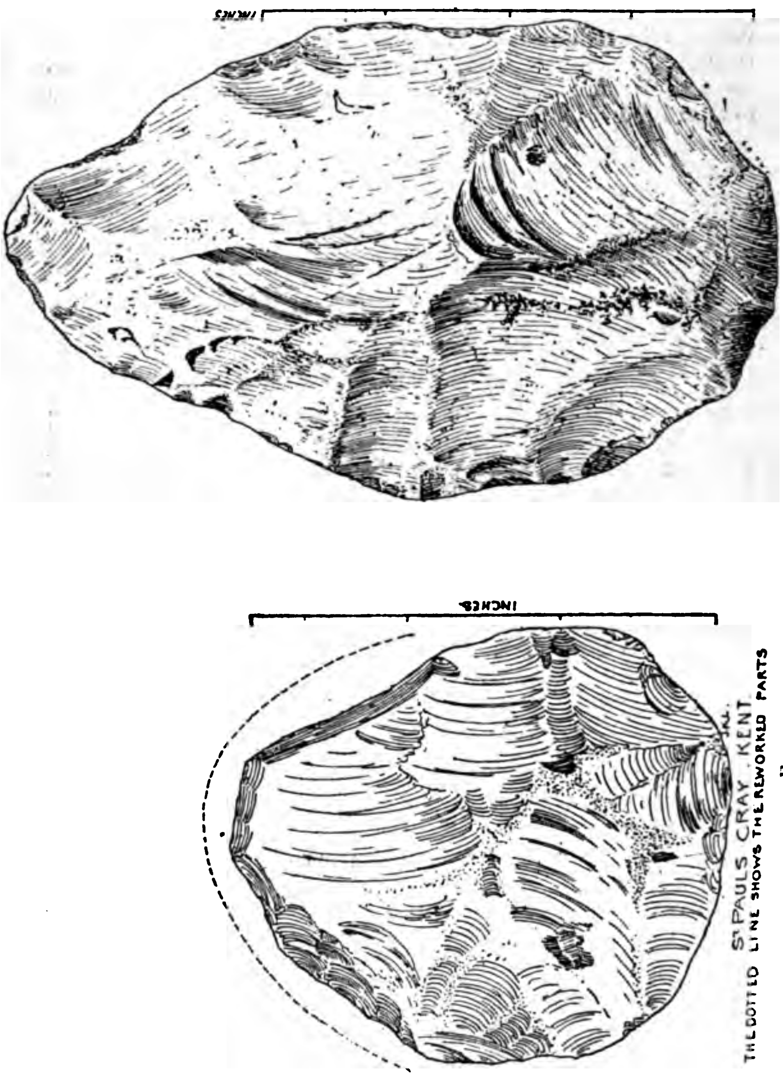
* On the day after the visit of the Association a white and striated drift, similar in composition and condition to the striated drift at Cockerhurst, was located near Knockholt station. Three fine Palæoliths were also found here on the same day.



FIGS. 3 AND 4.—LATER PALÆOLITHS, CRAY VALLEY.

in that district. Eocene pebbles are largely present, accompanied by deeply stained rolled flints and rolled chert. The details of Little Hoglands Bank were pointed out and reasons given for its artificial origin; rude pottery, many flakes, cores and rough hammer stones have been found here.

After tea the members walked to Well Hill, at and about Chelsfield passing over much Tertiary material. At the summit of Well Hill (610 feet O.D.) the interesting features of the locality received due attention. The hill is of interest as forming a high Tertiary outlier and a well-marked water-parting between the rivers Cray and Darent. The chief interest of the eminence is

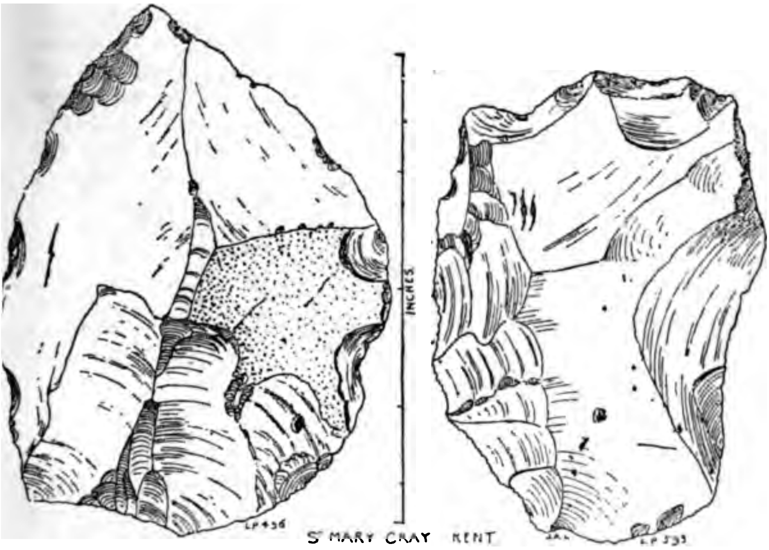


FIG. 5.—HEAVILY PATINATED PALÆOLITHIC FLAKES, BRICK EARTH OF THE CRAY, ST. MARY CRAY.

its high capping of gravel, the evidence for the antiquity of which may be briefly summed up as follows:—

1. The intense bleaching of the gravel.

2. The comparative rarity of Lower Greensand débris, showing, as Sir Joseph Prestwich long ago pointed out, that during the deposition of the gravel the rivers had hardly reached the "Lower Greensand."

3. The elevation of the deposit, some 430 feet above the present water courses of the area.

In order to grasp the configuration of the country during the deposition of the gravel, it is necessary to raise the surrounding country to well above 600 feet, but now the land slopes rapidly away to Chelsfield on the one hand and Shoreham on the other. The Well Hill gravel probably belongs to a very early stage of the Darent (see Figs. 6 & 7) and the great erosion demonstrable since its deposition gives an idea of the antiquity assignable to the Eolithic implements found in it (see Fig. 8). In order to observe the effects of this erosion, the party moved to the summit of the ridge. Here the Darent Valley was observed going well below the 200 feet contour: beyond it lies the Chalk plateau, to the south, the Gap in the Chalk escarpment cut by the Darent, and in the extreme distance the Lower Greensand escarpment. All these surface features have been developed since the deposition of the Well Hill gravel. It was to the small plateau at Cockerhurst Farm marked "Flood Plain" in Fig. 7 (Cockerice on the older O.S. plans) that special attention was directed. The country here is of Chalk with a slight capping of Thanet Sand; on the top of this is a thin drift of a varied character. It contains white angular flints, much striated, some showing work of Eolithic type (Figs. 9, 10, and 11), green-coated flints, quartzite, Oldbury stone, chert, and tertiary pebbles. This gravel at 470 feet O.D. forms a connecting link between the Well Hill gravel (610 feet O.D.) and the present course of the Darent at 187 feet O.D. It is not a Palæolithic gravel, for although Palæolithic

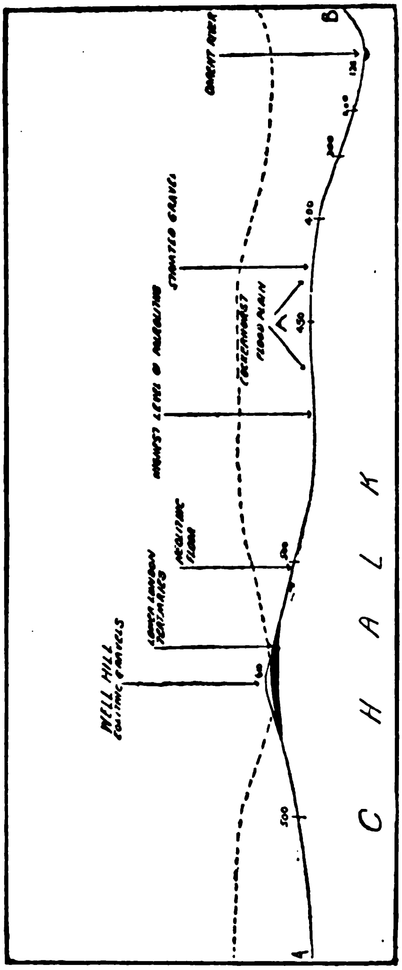
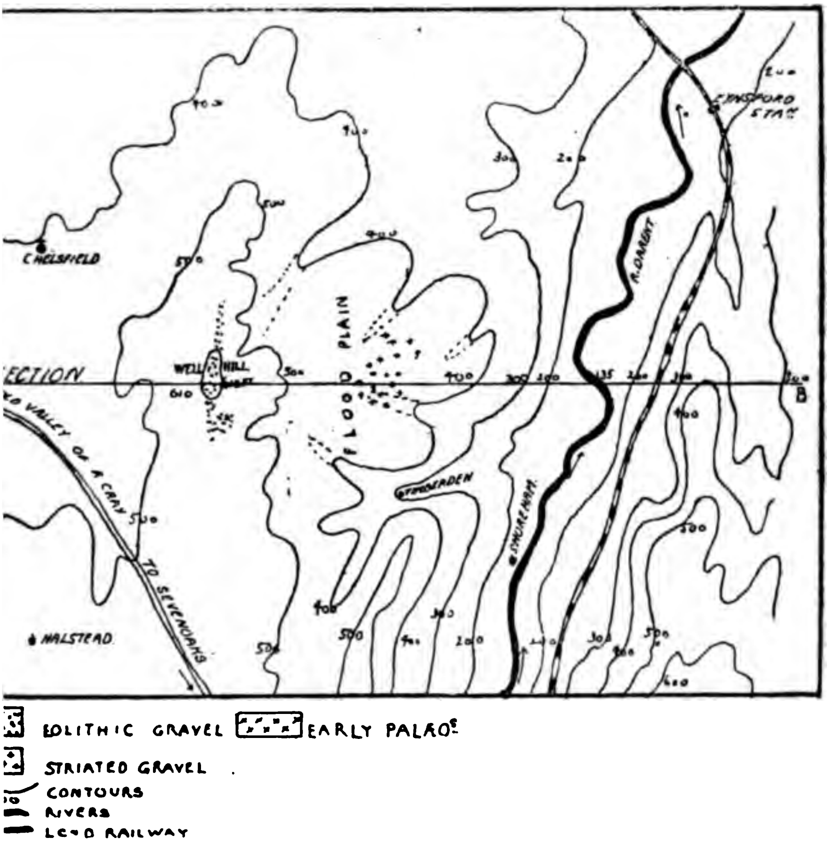


FIG. 6.—SECTION THROUGH WELL HILL TO THE DARENT VALLEY.

implements of a well-finished type occur on it (see Fig. 12) they have no geological relation to the drift, but were more probably dropped there by Palæolithic man as he traversed the area. Unrolled Palæolithic implements occur at a low level in the Darent Valley and closely resemble those from Cockerhurst. The plain here seems to be an old flood plain of the Darent, and it was suggested that the striated drift, which is almost wholly unabraded, was brought there by river ice. The absence of Palæolithic implements from this, and the Well Hill gravel was discussed Mr. Whitaker objected to negative evidence as an



IG. 7.—Sketch Plan of County near Well Hill; Contours Reproduced rom the Ordnance Survey Map with the Sanction of the Controller of H.M. Stationery Office.

unsatisfactory way of proving a pre-Palæolithic gravel. Messrs. Lewis Abbott and F. J. Bennett entered into the discussion. The Director mentioned that the association of Eoliths and Palæoliths had been claimed by Professor Boyd-Dawkins (*Man*, April, 1903, p. 59), resulting in the natural rejection of Eoliths as humanly fashioned forms; but the evidence thus quoted did not apparently come from a high gravel. At low levels, such an association might well exist.

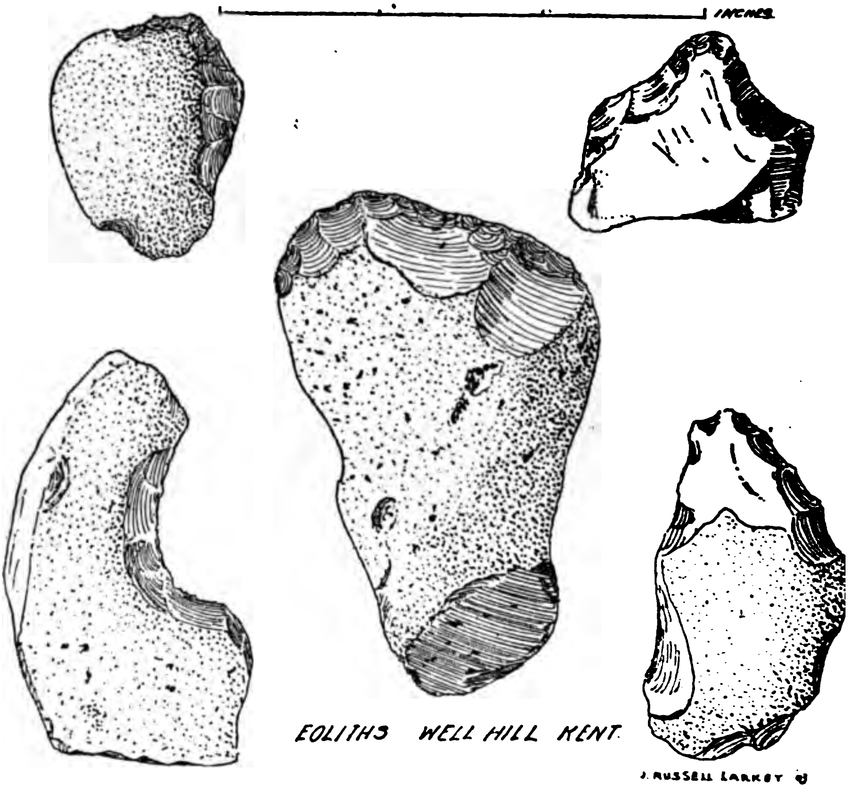
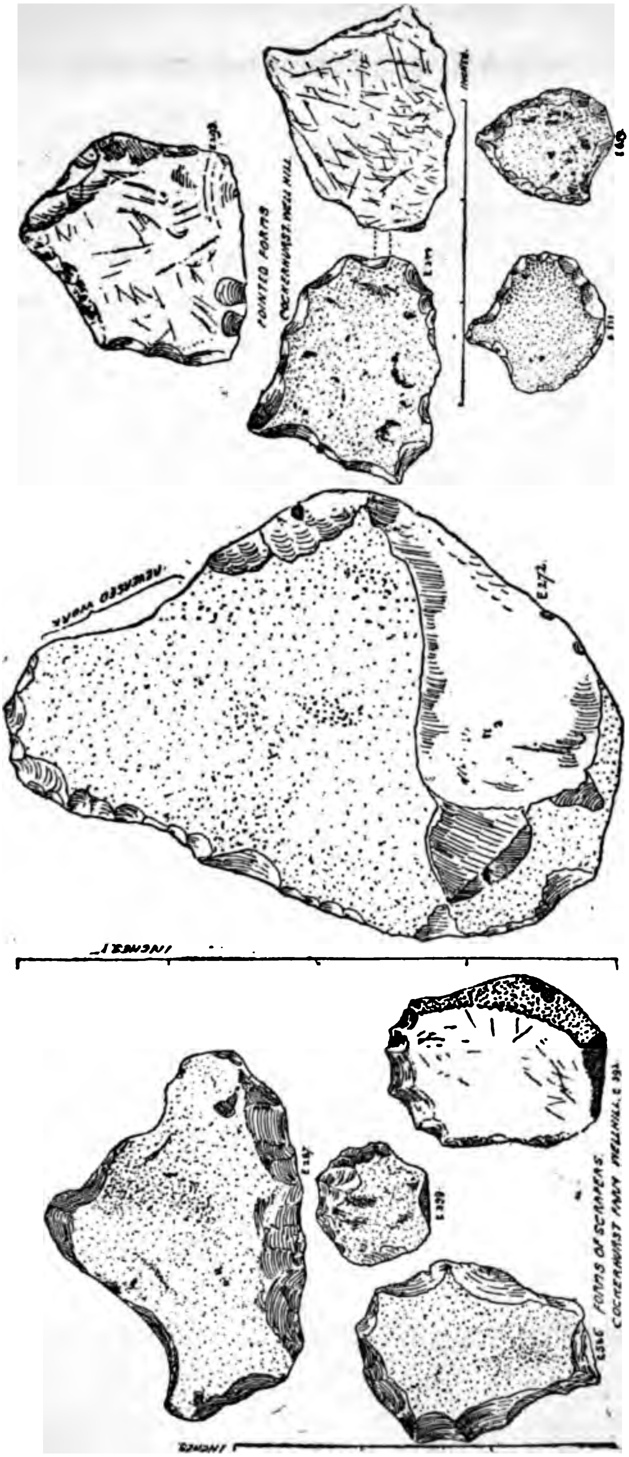


FIG. 8.—EOLITHIC IMPLEMENTS, WELL HILL GRAVEL.

The party then descended the eastern slope of Well Hill and inspected the swallow holes, marking a junction of Tertiaries and Chalk. The present action of swallow holes was described by Mr. Whitaker, and Mr. Bennett added some remarks on the early history of these features, for which he claimed upward hydrostatic pressure acting concurrently with downward denudation.



FIGS. 9, 10, AND 11.—STRIATED IMPLEMENTS, COCKERHURST FARM. MARKED AS "FLOOD PLAIN" IN FIG. 7.

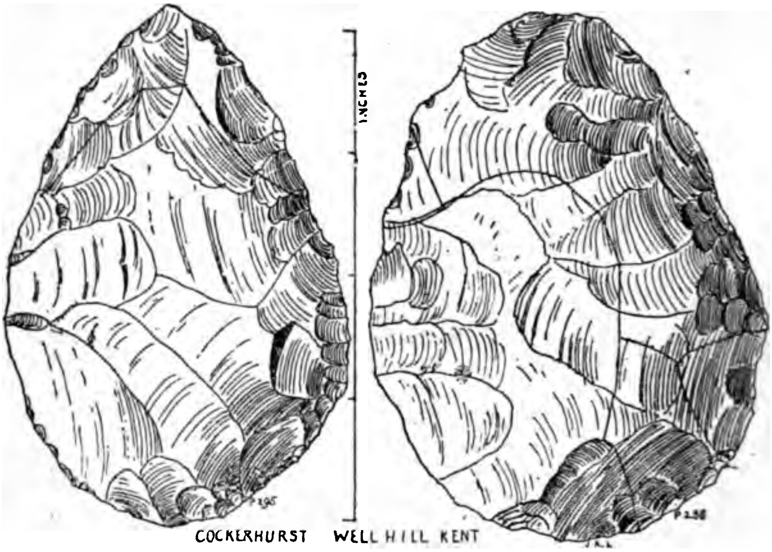


FIG. 12.—WELL-WORKED PALÆOLITHS. COCKERHURST FARM.

The proceedings then closed with a vote of thanks proposed by Mr. Whitaker, and the party returned to Chelsfield Station.

REFERENCES.

6-inch Sheet 16 S.E., section for Well Hill.
1-inch Sheet 28 N.E., section for Cray Valley.
Geological Map, Sheet 6. Price 8/6.
1898. SALTER, A. E.—"Pebbly and other Gravels in Southern England." *Proc. Geol. Assoc.*
1901. WHITAKER, W.—"Guide to the Geology of London," pp. 37, 40, 49 and 71.
1905. SALTER, A. E.—"On the Superficial Deposits of Central and parts of Southern England," pp. 7 & 8. *Proc. Geol. Assoc.*
*1905. LARKBY, J. RUSSELL.—"Notes on Prehistoric Man in West Kent." *Antiquary*, March and April parts.

The blocks illustrating this report were kindly supplied by Mr. Elliot Stock.

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* These notes require a correction with regard to Chert in the Well Hill gravel; it is there stated as not occurring in the drift.

EXCURSION TO HAMPSTEAD.

SATURDAY, SEPTEMBER 16TH, 1905.

Director: GRIFFITH HUMPHREYS.

Secretary: T. W. READER, F.G.S.

(*Report by* THE DIRECTOR.)

A PARTY of about 30 members met at Hampstead Heath Station in order to visit the Hampstead outlier of the Bagshot Sands.

The first halt was made near the Viaduct Pond, where the Director drew attention to the cliffs of Loam which here mark the junction of the Bagshot Sands with the London Clay. These exposures are the remains of the old brickfields mentioned in Mr. Whitaker's "Guide to the Geology of London." He also pointed out the course of the Fleet River, which flows from the Vale of Health Pond to the Lower Heath Ponds, and thence, at one time, to the Thames, thereby giving its name to Fleet Road, Fleet Street, and Fleet Prison. The party then proceeded to inspect a perfect miniature delta, formed by the silting up of one end of the Vale of Health Pond by the downwash of detritus from the sandy heights above.

On arriving at the "Firs," which is situated on a patch of preglacial pebble-gravel, Dr. Salter, at the request of the Director, drew attention to the gravel which caps the Bagshot Sand on the higher parts of the Heath. This is made up principally of flint pebbles derived from Tertiary Pebble Beds, but it also contains a fair amount of material derived from a distance, such as small quartz pebbles and pieces of Chert, which have been derived from the Hythe Beds of the Lower Greensand in the Wealden area. The presence of this material above 400· ft. O.D. on the north side of the Lower Thames Basin pointed, in his opinion, to the former existence of streams from that area. Since that time Earth movements have brought about an accentuation or modification of the synclinal trough of the Thames Valley. The great age of these gravels is thereby shown. Some years ago prolonged search showed presence also of small pebbles of jasper and dark chert or Lydian stone, which can also be derived from the Sandstone strata in Kent and Surrey. Several pieces of Lower Greensand Chert and Quartz pebbles were found by members.

The party then adjourned to Kenwood Farm, near the "Spaniards," where, by the courtesy of the Express Dairy Company, they were enabled to view the magnificent cliff of Bagshot Sand showing cross-bedding and seams of clay. Mr. Humphreys who had devoted the previous afternoon to scraping the section in order that it might be perfectly fresh, then read the following notes on the Geology of Hampstead:—

The sandy hill of Hampstead with its radiating valleys has been formed by circumdenudation, the sterility of the soil accounting for its having remained so long unenclosed prior to its purchase as a public park. The area of the Heath is 550 acres, the highest point being 450 ft. above Ordnance Datum. The London Clay on which the Bagshot Sands rest is a marine deposit, blue in colour, but rusts on exposure to the air. It contains embedded masses such as septaria, crystals of selenite, iron pyrites, and in certain zones many fossils. (A nautilus and some wood bored by teredo were here shown.)

This section of Bagshot Sand is the remains of an old sandpit, mentioned by Mr. Whitaker in his "Memoir of the Geology of London" (vol. i), and was visited by the Geologists' Association in March, 1895, under the directorship of Mr. A. M. Davies. Previous visits to other parts of the Heath were made in 1872-74-77-87, the first three under the direction of Mr. Caleb Evans, and in 1887 under Mr. Logan Lobley, in conjunction with the Middlesex Natural History Society. About midway up the cliff you will notice some thin clayey seams interstratified with the sands. Ferruginous bands of indurated Sandstone also occur, and on digging at the base we again encounter the "pan." The percolation of water through this highly ferruginous sand is the cause of the chalybeate wells at the junction with the impervious London Clay. The chalybeate spring in Well Walk attracted a deal of attention in the past, and during the first forty years of the eighteenth century Hampstead became a flourishing Spa, but ultimately fell into disrepute, morals and water both becoming contaminated. Mr. Allen Dick's Analysis of Bagshot Sand from the Hampstead outlier is as follows:—

Quartz	75	per cent.
Felspar	20	"
Grains attracted by Magnet	2	"
Clay	1	"
Zircons (in recognisable crystals) . . .	$\frac{1}{2}$	"
Rutiles	$\frac{1}{8}$	"
Tourmalines	$\frac{1}{10}$	"

The grains are sub-angular, giving evidence of wearing action on a sea-shore. A fragment of a fossil shell was stated to have been found in a ferruginous concretion, but no fossils are authoritatively recorded from the Hampstead Bagshots. The greatest thickness of Bagshot Sand under Hampstead Heath is 80 ft. This overlies 400 ft., of London Clay. Enormous quantities of sand have been artificially removed from the Heath, exposing roots of old trees and giving the surface its rugged appearance.

An excellent account of the Geology of Hampstead, with maps and diagrams, together with notes on the flora and fauna, will be found in Mr. Logan Lobley's capital little book entitled "Hampstead Hill."

A move was then made to the neighbourhood of North End, where a junction of the Clay and Sand is exposed near Wylde's Farm, and thence the party proceeded to the Valley of Erosion formed by the Leg of Mutton Stream, an affluent of the Brent. Although drainage has obliterated the stream, the valley remains, and this was traced to the source of the stream in a swamp that lies at the base of the Bagshot Sand Bay beneath the flagstaff.

Where the footpath from Oakhill Park cuts the Reddington Road another junction was made out, and the party finished a very successful afternoon by inspecting the excavations now being made behind the Parish Church for the University College Extension. Here the Director was able to show the Association the last traces of the West Bourne, a stream that flowed at one time through Bayswater into the Serpentine. This stream and its valley was filled in with hundreds of cart-loads of clay and rubbish about twenty years ago, but at a depth of 8 ft. the humus of the maiden soil was well shown by a black line giving the typical V shape of the valley in transverse section.

A very hearty vote of thanks was proposed by Mr. Whitaker, to which the Director responded.

REFERENCES.

Geological Survey Drift Map, London District, Sheet 1.

1872. W. Whitaker.—"Geology of the London Basin" and "Guide" to ditto.

J. L. Lobley.—"Hampstead Hill" (with full Bibliography).

(See also *Proc. Geol. Assoc.*, vol. ii, p. 40; vol. iii, p. 67; vol. iv, p. 155; vol. v, p. 160; vol. x, p. 148; vol. xiv, p. 97.)

ORDINARY MEETING.

Friday, November 3rd, 1905.

A. Smith Woodward, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: Miss Peggy de B. F. Bowen-Colthurst, Walter Cozens, Albert Ernest Kitson, F.G.S., The Librarian of the University of Aberdeen, J. H. Noall Stephenson, Miss Winifred West.

The meeting then resolved into a Conversazione. The following is a list of the exhibitors and their exhibits:

The President: Fossil fishes from the Lithographic Stone, Upper Jurassic, Lerida, Spain.

Dr. G. Abbott: Concretions from the Magnesian Limestone and Fish (Palæoniscus) from Sunderland.

Miss Caroline Birley: Marine Fossils from the Mikran Coast, Ormara Headland, Baluchistan, described by Mr. R. B. Newton in the *Geological*

Magazine, July, 1905; also a drawing of a new species of fossil crab (*Neptunus arabicus*) from the same locality, described by Dr. H. Woodward.

REV. J. F. BLAKE: Secondary fossils from India (Cutch), and from Brora, Sutherlandshire; and Foraminifera from the Irish Sea.

G. F. BROWN: Chalk fossils from Chipstead, Isle of Wight, Folkestone, and Eliot Mill, Bucks.

FREDERICK CHAPMAN: Aboriginal implements from near Melbourne; rubbing stone and shells from Black's Ovens, Hobson's Bay, Victoria.

G. E. DIBLEY: Teeth of Polyptychodon, mandible of Protosphyrena, *Hemiaster morissii*, Alectryonia and a Cephalopod (genus ?) from Burham.

ROBERT ELLIOTT: A series of Palæolithic implements from Kent, Sussex, Egypt, India, Tasmania, &c.; a fine specimen of *Ptychodus latissimus* from Galley Hill; milk tooth of *Elephas primigenius* from Crayford; and a specimen of Leptolepis from Solenhofen.

J. LOUIS FOUCAR: Fish and other fossil remains from the Blackheath Beds of N.W. Kent.

JAMES FRANCIS: Liassic lamellibranchs, gasteropods, brachiopods, and crinoids.

J. W. GARNHAM: Carved bottles and other ornaments in quartz, agate jade, &c.

UPFIELD GREEN: Cambrian and Gedinnian rock specimens from the valley of Ambleve (Stavelot), Belgium.

W. F. GWINNELL: Fossils from Monte Bolca, Solenhofen; rocks from the Western Highlands of Scotland, the Isle of Skye, Edinburgh, Derbyshire, &c.; and minerals from Switzerland and Ceylon.

MARTIN A. C. HINTON: A series of Eoliths from the Chalk plateau, with some later types (exhibited on behalf of Mr. B. Harrison of Ightham).

MISS M. S. JOHNSTON: Supposed fucoid (Helminthoides) from the Flysch, Rapallo, Italy; specimens of the pietra serena (micaceous sandstone) of which Florence is built; realgar deposited from the vapours issuing from the solfatara crater at Pozzuoli, Italy.

A. L. LEACH: Fossils from the Carboniferous Limestone of the Tenby District, together with a number of photographs of the same District.

P. A. B. MARTIN: Eoliths from the South Downs near Eastbourne, together with examples of Palæolithic and Neolithic flaking for comparison; also some flints flaked by mechanical action from a chalk wash mill.

B. C. POLKINGHORNE: A series of flint "scrapers."

T. W. READER: A collection of Eocene mollusca, &c., from the Paris Basin; and a specimen of "St Hilda's snake." (*Ammonites annulatus*) from Whitby.

F. W. RUDLER: Fossils from the London Clay.

DR. A. E. SALTER: Waterworn block of Ightham (Oldbury) Stone, from Dawes Heath, Rayleigh Hills, Essex; and a series of erratics from Drift deposits in Eastern Lincolnshire.

C. DAVIES SHERBORN: Facsimile of the oldest known map, being a plan of the gold mines of Jebel Zubara in the Egyptian Desert. The original, which was described by Lepsius, dates from the time of Sety mer en Ptah, the second king of the XIXth Dynasty, or about 1326-1300 B.C. (From Flinders Petrie, *Hist. Egypt*, III, 1905, p. 23).

LL. TREACHER: Palæolithic implements from Grovelands, Reading, and Neolithic implements from East Berkshire.

LL. TREACHER and H. J. OSBORNE WHITE: Fossils from the Phosphatic Chalk of Taplow.

W. J. STOKES: Russian diplomas granted to Dr. William Buckland in 1818.

J. C. THRUSSELL: Neolithic celts and other implements from Ireland and Japan.

A. H. WILLIAMS: Durness-Eriboll and other local rocks and microscopic sections.

G. W. YOUNG: Specimens collected during a cycling excursion in Auvergne.

GAZELLA DAVIESII, A NEW ANTELOPE FROM THE NORWICH CRAG OF BRAMERTON.

By MARTIN A. C. HINTON.

(Read December 1st, 1905.)

ALTHOUGH fossil remains of Antelopes had long been known to occur in the Pliocene, and later deposits of Europe and Asia, it was not until 1884 that the existence of a true Antelope in Britain, during Pliocene times, was first established. In that year Mr. E. T. Newton, F.R.S., communicated a paper to the Geological Society,* in which he described three horn-cores which had been obtained at various times from the Norwich Crag, and which he showed to be most nearly related to the Gazelles. In external form the fossils approached the existing *Gazella bennettii*, and on extending the comparison to casts of the anterior portion of the brain case, Mr. Newton found that they approached the living *G. dorcas* very closely in the structure of the frontal convolutions. Differences, however, were to be detected between the fossils and the recent species, and on the ground of these differences Mr. Newton established a new species, viz., *G. anglica*, in which he included all the Norwich Crag specimens which had come under his notice. In the interval between 1884 and 1892 various other Antelope remains were obtained from the Norwich Crag, and of these Mr. Newton published a short description, referring them to his *G. anglica.*†

Mr. A. S. Kennard recently acquired a number of specimens which had formed part of the collection of the late Mr. Bayfield, of Norwich. Among these was a horn-core of a small ruminant said to have been obtained from the Norwich Crag at Bramerton. Many years ago Mr. William Davies examined this specimen, and a label in his handwriting which accompanies it states:

"Horn Core of ——— (?) Capra or Antelope, not Sheep nor Deer."

Mr. Kennard very kindly submitted this specimen to me for identification, and as it appears to be of considerable interest I have ventured to describe it here.

The specimen comprises the larger part of the right horn-core with a portion of the frontal attached, so that (below) the upper parts of the orbital cavity and of the brain case are still preserved. The horn-core is laterally compressed,

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* E. T. Newton, "On the Occurrence of Antelope Remains in Newer Pliocene Beds in Britain, etc.," *Quart. Journ. Geol. Soc.*, vol. xl, p. 280, pl. xiv.

† E. T. Newton, "The Pliocene Vertebrata," *Mem. Geol. Survey*, p. 23.

slightly re-curved, and when viewed from the front shows a slight tendency to outward curvature, which is expressed in the slightly convex inner and slightly concave outer borders. Its surface is rugose and traversed by two longitudinal grooves—a well-defined, postero-internal one and a very slightly developed antero-external one. The anterior and posterior borders of the horn-core are rounded. The horn-core is supported on a long pedicle, and its slightly swollen base gives a burr-like appearance to the junction. The anterior border of the pedicle, when followed down towards the fronto-nasal suture, is at first rounded and then a little depressed, and, at its lowermost part, the apex of the deep frontal fossa is sunk in it, from the floor of which a deep foramen is seen passing in to the frontal bone. No doubt when perfect a large supra-orbital foramen pierced the orbital roof just below this point, but unfortunately this region is missing in the specimen. What is left of the inner wall of the orbit slopes rapidly inwards, so that when perfect it is evident that the orbits must have approached quite near to each other beneath the brain. Above on the postero-external part of the pedicle is seen a clearly marked little pit placed so that the supra-orbital rim formed its outer boundary, but this rim unfortunately has been broken off in the specimen. The frontal is so imperfect that none of the sutures are preserved. It is therefore not possible to ascertain the width of the skull or the other characters usually decided by such means. The broken edge of the inner side shows the internal and external frontal plates so near to each other that the intervening tissue is only of the ordinary cancellous kind, but where the supra-orbital rim has been split off, and especially towards the front, a few air sinuses are to be seen.

A comparison of our fossil with *Gazella anglica* and with the series of recent Gazelle skulls in the College of Surgeons, leaves no doubt as to the justification of referring it to the genus *Gazella*. The fossil differs from *G. anglica* in its much smaller size, less compressed horn-core, which has a slight outward curvature instead of being perfectly straight, and the relatively and absolutely longer pedicle. The longitudinal grooves traversing the horn-core appear to be absent in Mr. Newton's species, but this difference is probably not an important one. The pit behind the pedicle, so far as it is preserved, appears to have been much shallower than in *G. anglica*.

There appears to be a somewhat important diversity in the form of the upper part of the frontal fossa in the various species of Gazelle. As a rule above the supra-orbital foramen, which passes from the floor of the frontal fossa directly into the orbit, a much smaller foramen is present which passes into the frontal bone and pedicle. In some species the mouth of this upper foramen is concealed by being tucked under a ledge of bone forming the apex of the triangular frontal fossa; in others, the frontal fossa seems to be more extensive, the ledge is done away with and the foramen is quite open to view. This latter condition is seen in the fossil example before us, and as a consequence the frontal fossa, instead of being pointed above and so perfectly triangular, is there produced into a rectangular addition. In *G. anglica*, as seen in the two figured and type specimens preserved in the Museum of Practical Geology, the frontal fossa is perfectly triangular, and under its apex is tucked the chief orifice of the upper foramen. In addition to this mouth, however, in each specimen there is seen on the surface of the frontal bone, above the frontal fossa, a minute foramen which passes into the upper foramen proper.

In a skull of the recent *G. dorcas* in the College of Surgeons (No. 1359, New Catalogue), the horn-core and surrounding parts are very similar to the fossil, and the two agree closely in size. The frontal fossa is quite triangular, and the supra-orbital foramen passes directly into the orbit a little below the apex. Tilting the skull back one sees the small upper foramen concealed under the apex. In a female skull of this species (No. 1361) the frontal fossa is quite shallow, and there is no upper foramen as in the male.

An adult male skull referred to *G. bennettii* (No. 1363) shows, in my opinion, that the grooving of the horn-core is only an individual character, since here the right horn-core has a strong longitudinal groove, but on the left side this is not so well developed. No foramen was seen above the large supra-orbital foramen. In a very old female skull of this species (No. 1364) a little foramen was seen on each side above the supra-orbital foramen, and that on the right side succeeded in piercing the orbit. *G. bennettii* is very much larger than the fossil, and the pit behind the pedicle is much deeper.

A skull of *G. muscatensis* (No. 1368C) is noteworthy, since here the upper foramen is quite unconcealed. In *G. picticaudata* (1368D) this foramen does not pass into the bone at once, but firstly into the supra-orbital foramen, and then a branch leaves the wall of the latter and passes into the skull. The pit behind the pedicle is very deep in this skull, but quite shallow in that of *G. muscatensis*.

In the skull (No. 1365), referred to *G. euchore*, the pit at the back of the pedicle is fairly large. The most important fact is that in this example the frontal fossa above is nearly rectangular, and that above the large supra-orbital foramen there is a large foramen passing into the frontal bone. Making allowance for the much greater size of this species this region of the skull in it presents an appearance very similar to that of the fossil.

Since Mr. Newton, in his essay, has entered very fully into the question of the allied Antelopes, it is unnecessary for me to

TABLE OF MEASUREMENTS (MILLIMETRES).

	G. daviesii, N. Sp.	*G. N. Sp.* ? (undescr.) M. P. G.	*G. anglica* Type, M. P. G.	*G. anglica*, figd. M. P. G.	*G. anglica*, M. P. G. Norwich Crag ?	*G. dorcas* (R. C. S. No. 1359).	*G. bennettii* (♂ R.C.S. No. 1363).	*G. bennettii* (♀ R. C. S. No. 1364.)
Height of pedicle, middle of inner side	11·0	14·0	10·0	—	—	10·0	14·0	—
Antero-posterior diameter of horn-core at base	16·8	22·0	33·5	27·8	29·5	15·8	26·5	10·5
Ditto, relative	100	100	100	100	100	100	100	100
Transverse diameter of horn-core at base	12·8	18·0	21·5	18·0	16·5	13·2	22·8	9·5
Ditto, relative	76·19	81·81	64·18	64·74	55·93	83·54	86·03	90·47

carry the comparison further. The distinctions of form and size between the present fossil on the one hand, and *G. anglica* and the recent species on the other, are sufficient, it is thought, to show that the former is specifically distinct from any of the latter. Moreover, there is, so far as I am aware, no extinct species of Gazelle with which it can be satisfactorily identified. Under these circumstances I have to suggest a specific designation for it, and it seems to me suitable to name it *G. daviesii* in order to associate it with Mr. William Davies, who, with his customary judgment, clearly indicated the affinities of this specimen so many years ago.

Before concluding, I would mention that in the Museum of Practical Geology there is a much rolled and damaged right horn-core which was obtained by Mr. H. B. Woodward from the Norwich Crag at Thorpe. A good deal of the frontal is attached and it shows part of the brain cavity tolerably well. It clearly is referable to *Gazella*, and indicates an animal half as large again as ours with a still less compressed horn-core, and the pit behind the pedicle is deeper than in our specimen. It certainly is not referable to *G. anglica*, and in my opinion represents a species distinct from that which I have here named *G. daviesii*. Since I have not up to the present studied it very closely, I do not on this occasion venture to propose a new name for it.

In conclusion, I have to express my best thanks to Mr. A. S. Kennard, F.G.S., for the loan of the specimen; to Dr. C. W. Andrews, F.G.S., Mr. R. H. Burne, F.Z.S., Dr. F. L. Kitchen, F.G.S., and Dr. C. I. Forsyth Major, F.Z.S., for their courtesy; and especially to Mr. E. T. Newton, F.R.S., for the great assistance afforded by his paper and his kindly personal advice.

ON SECTIONS IN THE HOLOCENE ALLUVIUM OF THE THAMES AT STAINES AND WARGRAVE.

BY A. S. KENNARD, F.G.S., AND B. B. WOODWARD, F.L.S., F.G.S.

IN 1890 the following account of a Holocene section at Staines was published by one of us, being an extract from a letter by the late Mr. J. Allen Brown :

"The section at Staines, where the deposit occurs in which I found the mollusca, is on the left bank of the Thames, fully a mile west of Staines on the tow-path towards Old Windsor. The present channel of the river has been eroded in its old bed, which was then at a higher level than the present stream. The lower part of the bank is there a mass of shells intermixed with small fragments of carbonised wood and small nodules of race. The bed is surmounted by brickearth 3 or 4 ft. thick. The deposit is so thick in organic remains that I intend at the earliest opportunity to again investigate it, and at a future time to lay a fuller account of it before the Geologists' Association."*

Unfortunately this intention was never carried out, but our friend, Mr. A. Loydell, has devoted some considerable time to this interesting deposit, and he most kindly placed his notes and specimens at our disposal.

The section is as follows:

Bed 1.—Surface soil: 1 ft.

Bed 2.—Consisting of large black flints mixed with smaller black well-rounded pebbles derived from the lower tertiaries: 2 ft. 6 in.

Bed 3.—A brickearth containing several species of mollusca, of which the most noteworthy is *Hygromia rufescens*, since it does not occur in the beds below: 3 ft.

Bed 4.—A marl practically composed of shells: 1 ft.

Bed 5.—Calcareous loam. Several species of mollusca were also obtained from this bed, which also contained calcareous concretions, fragments of flint, and some plant remains, including leaves and stem of *Cratægus oxyacantha*, Linn., and *Salix viminalis*, Linn., as well as small portions of aquatic plants and rushes. This bed also yielded two teeth of the pike (*Esox lucius*, Linn.), and a tooth of either dog or wolf: 2¼ ft.

Caddis worm cases, probably of *Limnephilus flavicornis* were also met with in Bed 4.

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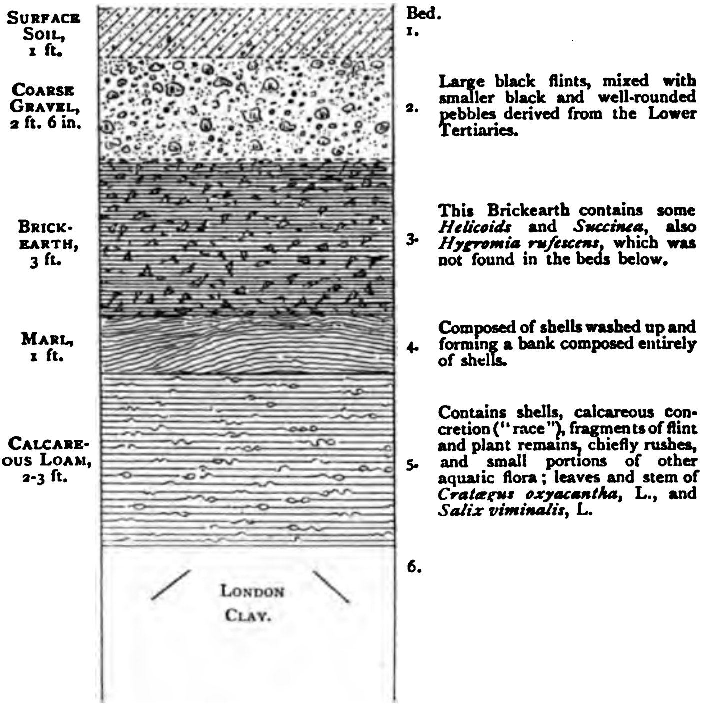
* *Proc. Geol. Assoc.*, vol. ix, p. 339.

LIST OF MOLLUSCA.

* *Vitrea crystallina* (Müll.), 9 examples.
* „ *nitidula* (Drap.), 9 examples.
* „ *radiatula* (Alder), 1 example.
Zonitoides nitidus (Müll.), 7 examples.
* *Arion ater* (Linn.), 2 granules.
Punctum pygmæum (Drap.), 4 examples.

HOLOCENE DEPOSIT, NEAR STAINES.



2. Large black flints, mixed with smaller black and well-rounded pebbles derived from the Lower Tertiaries.

3. This Brickearth contains some *Helicoids* and *Succinea*, also *Hygromia rufescens*, which was not found in the beds below.

4. Composed of shells washed up and forming a bank composed entirely of shells.

5. Contains shells, calcareous concretion ("race"), fragments of flint and plant remains, chiefly rushes, and small portions of other aquatic flora; leaves and stem of *Cratægus oxyacantha*, L., and *Salix viminalis*, L.

Pyramidula rotundata (Müll.), rare.
* *Helicella itala* (Linn.), 5 examples.
* *Hygromia hispida* (Linn.), common.
* „ *rufescens* (Penn.), 3 examples.
* *Vallonia pulchella* (Müll.), fairly common.
* „ *excentrica*, Sterki, fairly common.
* *Helicigona arbustorum* (Linn.), fairly common.
* *Helix nemoralis*, Linn., 1 example.
Cochlicopa lubrica (Müll.), rare.

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* Not previously recorded from Staines.

* *Cæcilioides acicula* (Müll.), 2 examples.
Jaminia muscorum (Linn.), rare.
* *Vertigo minutissima* (Hart.), 1 example.
* „ *pygmæa*, Drap., 1 example.
* *Clausilia laminata* (Mont.), 2 examples.
Succinea putris (Linn.), 1 example.
„ *elegans*, Risso, common.
Carychium minimum, Müll., 4 examples.
Ancylus fluviatilis, Müll., rare.
* *Acroloxus lacustris* (Linn.), 2 examples.
* *Limnæa auricularia* (Linn.), common.
„ *pereger* (Müll.), rare.
„ *palustris* (Müll.), rare.
„ *truncatula* (Müll.), common.
„ *stagnalis* (Linn.), rare.
* *Amphipeplea glutinosa* (Müll.), 1 example.
Planorbis corneus (Linn.), 2 examples.
„ *albus*, Müll., common.
* „ *stroemii*, West., 12 examples.
* „ *crista* (Linn.), rare.
„ *carinatus*, Müll., common.
„ *umbilicatus*, Müll., 4 examples.
„ *vortex* (Linn.), 1 example.
* „ *spirorbis* (Linn.), 7 examples.
„ *contortus* (Linn.), common.
* „ *fontanus* (Lightf.), 1 example.
Physa fontinalis (Linn.), rare.
Bithynia tentaculata (Linn.), common.
„ *leachii* (Shepp.), common.
Valvata piscinalis (Müll.), common.
Valvata cristata, Müll., common.
Neritina fluviatilis (Linn.), common.
Anodonta cygnæa (Linn.), rare.
Sphærium corneum, Linn., common.
Pisidium amnicum (Müll.), common.
* „ *supinum*, A. Schm., rare.
* „ *henslowianum* (Shepp.), rare.
* „ *subtruncatum*, Malm., rare.
* „ *pulchellum*, Jenyns, rare.
„ *pusillum* (Gmel.), common.
* „ *nitidum*, Jenyns, common.
* „ *obtusale*, Pfr., rare.
* „ *gassiesianum*, Dupuy, rare.

NOTES ON THE SPECIES.

In this country it has usually been considered that we had only one species of *Vallonia*, namely, *V. pulchella* (Müll.), with a

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* Not previously recorded from Staines.

variety *costata* (Müll.), but Sterki has conclusively shown* that there are really three species which can be easily distinguished, both by the shell and the soft parts. These are *V. pulchella* (Müll.), *V. costata* (Müll.), and *V. excentrica*, Sterki. Of these the first and the last occurred in the Staines deposit not infrequently. All three forms are without doubt widely distributed in these islands at the present time, and they were also common both in Holocene and Pleistocene times.

Hygromia hispida (Linn.), was fairly common, nearly all the examples being the form that used to be called *Helix concinna*, Jeff. There was, however, an immature example of a high spired form, which as yet we are unable to identify. It is by no means improbable that there are two distinct forms included under the name *hispida*, one the true form, and the other *rubiginosa*, A. Sch., but as yet we have not had sufficient material to determine this point satisfactorily.

Helicella itala (Linn.) Although this species is known from several Pleistocene beds (it was fairly common at Barnwell), and is abundant in the various rain-washes in the south of England, yet it is an extremely rare form in a Holocene river deposit, the reason being that this species is an inhabitant of open country. It has certainly extended its range very much in modern times, as the old woodland has been destroyed.

Vertigo minutissima (Hart.), is extremely rare in a fossil state in these islands. It is known from the Pleistocene of Ightham and Westminster and the Holocene of Westbury-on-Severn and Elie, Fifeshire. It is a widely distributed though rare species.

Amphipeplea glutinosa (Müll.) This species has only once been recorded as fossil, viz., from the Pleistocene of Hoxne, by Mr. Clement Reid,† and in this case no examples were preserved, since they were so fragile that they fell to pieces. Only one example was obtained from Staines, but though it is an immature specimen we have no doubt of the identification.

Planorbis stroemii, West., is an extremely interesting form. It was first detected by us from the Holocene of Walthamstow, and it is now known from the site of the New Scotland Yard, and that of the Houses of Parliament; from Bettridge Road (Fulham), Kew, Clifton Hampden (Oxfordshire), and Tooley Street. Dr. A. C. Johansen, who identified the species for us, informs us that it is now living in Siberia, Finland, and Northern Scandinavia, while it occurred in Denmark solely in deposits of the oak period (Neolithic age).

It will be noted that no less than nine species of *Pisidium* are listed, being all the living English species and one form, *P. supinum*, which has not yet been detected living in this country.

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* *Proc. Acad. Nat. Sci. Philad.* 1893, p. 278.

† *British Assoc. Report*, 1896, p. 4c5.

The examples of *Bithynia leachii* (Shepp.) are exactly the same as recent examples obtained from the Thames. This form seems characteristic of all the Thames Holocene deposits, and is the only British recent form, for the so-called variety *elongata* of Jeffreys is not worth noting. In the Pleistocene, however, we have another form known on the continent as *Bithynia inflata*, Hartm., and which is known from Crayford, Ilford, and West Wittering. At Swanscomb, on the other hand, the examples of *B. leachii* are the same as the recent British form. We have, therefore, an extremely interesting condition of things. Here is a form common in the oldest fossiliferous Pleistocene deposit in the Thames Valley replaced by another form in the newer Pleistocene beds, which in turn is replaced by the older form in the Holocene and at the present time. It is a problem for which we can offer no solution.

WARGRAVE.

For the material from this locality we are indebted to Mr. H. J. Osborne White.

He most kindly forwarded a box of shell marl which occurred at a depth of two feet from the surface of a meadow subject to occasional flooding. The section is on the left (Oxfordshire) bank of the Thames opposite the village of Wargrave. The section consists of:

(1) Loamy soil.
(2) Gravel.
(3) Compact loam or clay, with shelly seams, and thus greatly resembles the Staines section.

Twenty-three species of mollusca were obtained from the material, viz.:

Zonitoides nitidus (Müll.), 2 examples.
Arion ater (Linn.), 6 granules.
Agriolimax agrestis (Linn.), 1 example.
Hygromia hispida (Linn.), common.
Vallonia pulchella (Müll.), 4 examples.
Cochlicopa lubrica (Müll.), 1 example.
Limnæa pereger (Müll.), common.
  „ *truncatula* (Müll.), 1 example.
  „ *stagnalis* (Linn.), 1 example.
Planorbis stroemii, West., rare.
  „ *vortex* (Linn.), 1 example.
  „ *spirorbis* (Linn.), 1 example.
  „ *contortus* (Linn.), 2 examples.
  „ *carinatus*, Müll., rare.
  „ *umbilicatus*, Müll., rare.
Bithynia tentaculata (Linn.), common.
  „ *leachii* (Shepp.), rare.

Valvata piscinalis (Müll.), rare.
„ *cristata*, Müll., rare.
Neritina fluviatilis (Linn.), common.
Sphærium corneum (Linn.), common.
Pisidium amnicum (Müll.), 1 valve.
„ *henslowianum* (Shepp.), 1 valve.

These are all well-known Thames Holocene shells, and need no extended notice.

During the past few years we have had the opportunity of examining a very large quantity of Holocene material from various localities in the Thames Valley, and it is indeed noteworthy how the same molluscan fauna has been obtained from each deposit. The localities are Walthamstow, Canning Town, Tooley Street, Bermondsey, Staines, Wargrave, Clifton Hampden, and three localities in Westminster. The land mollusca are, of course, accidental in their occurrence, but even with these many of the species will be found to occur in each locality. Among the fluviatile forms one of the most constant is *Planorbis stroemii*, which is abundant in nearly every locality. We have not yet detected this species in any Pleistocene bed, and it was absent from both Crossness and Tilbury. At Clifton Hampden it was the most abundant *Planorbis;* at Staines it was rare; at Walthamstow, in the older alluvium, it was far more abundant than its near ally *P. albus*, but in the more recent deposits it was extremely scarce, though *P. albus* was very common, and it is quite possible that in these recent deposits it was only a derivative from older beds. In the Roman alluvium at Tooley Street it occurred sparingly, and in all probability at this period it was fast dying out. When it first came into the Thames river system, and why it should have become extinct, are problems to which as yet we have no clue. It is the custom in some quarters to speak slightingly of these recent deposits, but the problems connected with them and their contained fauna and flora are of the greatest interest, and are by no means solved.

All the species of *Planorbis* which occurred at Staines were also obtained at Walthamstow and Clifton Hampden, and, with the exception of *P. crista*, at Tooley Street. Other forms which are characteristic of the Thames deposits are *Bithynia leachii* (Shepp.), *Neritina fluviatilis* (Linn.), *Limnæa auricularia* (Linn.), *Sphærium corneum* (Linn.), and the several species of *Pisidium*. This homogeneous nature of the Holocene molluscan fauna is in marked contrast with the Pleistocene deposits of the Thames, where there are always marked differences between the species from various deposits. Thus in the genus *Planorbis*, *P. albus*, Müll., is abundant at Swanscomb, and *P. glaber* is rare, whilst a similar condition of things was found at Grays. At Crayford, on the other hand, *P. glaber* is the most abundant form, only a few examples of *P. albus* having been noted, whilst severa specimens of *P. arcticus*, Beck, were also found. There can be no doubt that these differences arise from varying local conditions, and it may be possible in the future to deduce these conditions from the distribution of the mollusca, but as yet we are unable to do so, and we must content ourselves with the careful collection of facts.

ORDINARY MEETING.

FRIDAY, DECEMBER 1ST, 1905.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

The following were elected members of the Association: Herbert T. Evans, M.A., Arthur Thomas Todd-White, M.R.C.S., L.R.C.P., L.S.A., Miss Ella Bridgman Walker.

The following papers were then read: "Gazella Daviesii—A New Antelope from the Norwich Crag of Bramerton," by Martin A. C. Hinton; "On Sections of the Holocene Alluvium of the Thames at Staines and Wargrave," by A. S. Kennard, F.G.S., and B. B. Woodward, F.L.S., F.G.S.

ORDINARY MEETING.

FRIDAY, JANUARY 5th, 1906.

CAPTAIN A. W. STIFFE, F.G.S., Vice-President, in the Chair.

The following were elected members of the Association: Miss Charlotte Chamberlain, George M. Davies, William G. Fearnsides, M.A., F.G.S., J. W. Parry, C.E., and Walter P. Young, F.R.M.S.

Messrs. W. P. D. Stebbing and H. Kidner were elected Auditors of the accounts of the Association for the year 1905.

The following lecture was then delivered: "On the Geology of the Country around the Sogne Fjord and the Hardanger Fjord, Norway," by Horace W. Monckton, V.P.L.S., F.G.S.; illustrated by lantern slides.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 2ND, 1906.

A. SMITH WOODWARD, LL.D., F.R.S., President, in the Chair.

Messrs. H. Fleck and A. L. Leach were appointed Scrutineers of the ballot.

The following report of the Council for the year 1905 was then read:

THE numerical strength of the Association on December 31st, 1905, was as follows:

Honorary Members	15
Ordinary Members—	
a. Life Members (compounded)	169
b. Old Country Members (5s. Annual Subscription)	2
c. Other Members (10s. Annual Subscription)	408
Total	594

This shows an increase of three as compared with the corresponding figures for the previous year.

During the year thirty-four new members were elected.

The Council regret that the Association has lost seven members by death: James Roberts Brown, Dr. William Clement Daniel, Frederick W. Hutton, Thomas William Shore, Jeremiah Slade, Edwin Sloper, and Rev. Francis A. Walker.

Thomas William Shore, F.G.S., who joined the Association in 1897, was one of the founders of the Hampshire Field Club, in 1855, and arranged its excursions thenceforward until his death. On coming to London in 1896, he founded the Balham Antiquarian Society and also helped largely in the work of the London and Middlesex Archæological Society. Several Geological papers from his pen have appeared in the papers of the Hampshire Field Club and he has done other good work, notably on antiquarian subjects. He will be remembered as an able organiser and leader of excursions.

The death of Jeremiah Slade has deprived the Association of one of its founders. Although not known to scientific workers by published researches, he had for half a century been a strenuous teacher and a helper to others. He was enabled, comparatively early in life, to retire from business and devote his whole attention to natural history. While resident in the north

GEOLOGISTS' ASSOCIATION.

Dr. Income and Expenditure for the Year ending Dec. 31st, 1905. Cr.

	£	s.	d.
To Balance from 1904	90	9	5
„ Life Compositions	32	10	0
„ Admission Fees	16	0	0
„ Annual Subscriptions	195	1	6
„ Dividends on Nottingham Corporation Stock ...	32	6	11
„ Sale of Publications	13	5	6
„ Grant from Royal Society towards cost of publishing Dr. Rowe's papers	50	0	0
	£429	13	4

	£	s.	d.
By Printing "Proceedings"	115	8	0
„ „ Monthly Circulars	17	17	0
„ Miscellaneous Printing...	10	18	6
„ Illustrating "Proceedings" and Circulars ...	17	18	3
„ Postage, Telegrams and Messages	39	3	2
„ Addressing	7	10	0
„ Library	8	8	11
„ Attendance, Lighting, Lantern, etc., at Evening Meetings	16	1	0
„ Excursions	6	3	0
„ Insurance...	2	15	0
„ Stationery	2	9	4
„ Miscellaneous Expenses	0	2	1
„ Purchase of £52 7s. 3d. Nottingham Corporation Stock	50	0	0
„ Balance at Bank of England, Dec. 31st, 1905...	134	19	1
	£429	13	4

We have compared the above account with the vouchers, and find it correct.
We have also verified the investment of £1,161 1s. 8d. Nottingham Corporation Stock.

January 18th, 1906.

W. P. D. STEBBING, }
HENRY KIDNER, } *Auditors.*

of London he was a member of the once flourishing Islington Literary and Scientific Society, and it was at a conversazione of that Society, on 28th October, 1858, that the formation of the Geologists' Association was first discussed. Mr. Slade was among those who took part in the provisional committee who thus became founders of the Association. In 1866 he assisted in the formation of the North London Naturalists' Club, the earliest field-club devoted to the study of natural history in the neighbourhood of London, and of which he was chosen Secretary. For 20 years (1865-85) he was a teacher of geology, mineralogy, zoology, and botany at the Working Men's College, the Birkbeck Institution, and the City of London College. A constant attendant at the excursions of the Association, his extensive and accurate information on many subjects, and his knowledge of plants especially, were ever cheerfully and unostentatiously communicated to inquiring students. The only paper contributed by him to the Association was entitled, "Notes on the Microscopic Structure of the Basalt of Swallow Cliff and Uphill" (*Proc.*, vol. vii, pp. 112, 113). His services to science are not recorded on paper, but they have borne good fruit and will long be remembered by a circle of friends whose love of nature has been inspired and cultivated by his disinterested labours.

The finances of the Association are in a satisfactory condition. The ordinary income in 1905 was £289 3s. 11d., as compared with £267 1s. od. in the previous year. There was an increase of over £14 in Annual Subscriptions—due in great part to recovery of arrears—but there was a decrease of £4 in the Admission Fees. Besides the ordinary income the Association has received a special grant of £50 from the Royal Society towards the cost of publishing future papers by Dr. Rowe on the White Chalk. This sum has been invested until such time as it is required. The ordinary expenditure for the year 1905 has been £224 14s. 3d. as compared with £298 17s. 10d. for 1904. The decrease has occurred almost entirely in the cost of illustrating the PROCEEDINGS. From the balance in hand the Council propose to invest a further sum of £50.

The PROCEEDINGS for the year have been issued in 5 parts, which form the commencement of vol. xix. They comprise 246 pages of text, 5 plates, and 33 figures. The thanks of the Association are due to the several authors for their communications, and also to the Council of the Geological Society, the Controller of H. M. Stationery Office, the Editor of the "Naturalist," Elliott Stock, Esq., J. Hopkinson, Esq., F.G.S., H. Preston, Esq., F.G.S., and the President, for their courtesy in granting permission to use certain blocks, clichés, etc., employed for the illustration of these parts of the volume.

The additions to the Library during the year consist, as usual, chiefly of volumes of Transactions received from other Societies in exchange, together with a few overprints of papers kindly presented by individual authors.

In addition to recently published 1-in. colour-printed maps the following memoirs have been received through the courtesy of the Director of the Geological Survey:

The North Staffordshire Coalfields; The Country South and East of Devizes; The Country between Derby, Burton-on-Trent, Ashby-de-la-Zouch, and Loughborough; The Country around Cork and Cork Harbour; and The Geology of Mid-Argyll.

The question of binding alluded to in the last Report has been further considered, and after £6 7s. 2d. had been spent on arrears of binding, a small committee was appointed to report on the general question of the future of the Library. The matter was ultimately referred to a committee of the whole Council, and at a meeting held in the Library on December 1st it was resolved to recommend that in view of the expenditure necessary to adequately maintain the Library in an efficient state, and the small use made of Library by the members of the Association, the Library be handed over to the authorities at University College as a free gift, on condition that the members of the Association have access in perpetuity to the whole of the Science Library in the College, with all their present privileges, and that the College authorities undertake to maintain the Library of the Association in an efficient condition, and to grant access to the Library to members of the Association up to 8.0 p.m. on meeting nights, of which there will be not more than 12 in the year; the Association on their part undertaking to continue the series of exchanges with other Societies as at present.

The following is a list of the papers read at the evening meetings:

"Modern Methods in the Study of Fossils," being the address of the President, A. SMITH WOODWARD, LL.D., F.R.S.

"On the Relative Ages of the Stone Implements of the Lower Thames Valley," by MARTIN A. C. HINTON and A. S. KENNARD, F.G.S.

"The Chalk Area of N.E. Surrey," by G. W. YOUNG.

"The Geology of Central Wales," by HERBERT LAPWORTH, F.G.S.

"The Igneous Rocks of the Welsh Border," by PROF. W. W. WATTS, M A., F.R.S.

"Gazella Daviesii—A new Antelope from the Norwich Crag of Bramerton," by MARTIN A. C. HINTON.

"On Sections of the Holocene Alluvium of the Thames at Staines and Wargrave," by A. S. KENNARD, F.G.S. and B. B. WOODWARD, F.L.S., F.G.S.

Lectures were delivered by PROF. C. GILBERT CULLIS, D.Sc., F.G.S., on "The Third Issue of the British Association Geological Photographs"; by PROF. H. A. MIERS, M.A., F.R.S., on "The Diamond Mines of South Africa"; and by W. J. HOLLAND, LL.D., Director of the Carnegie Museum, Pittsburgh, on "Explorations for Fossil Bones in Western North America, with special reference to the Skeleton of Diplodocus," of which a plaster cast is now mounted in the British Museum (Natural History).

The thanks of the Association are due to all these gentlemen.

The Excursions have been more than usually successful and well attended, and none were interfered with by the weather. It is regretted that the Newbury Excursion unavoidably clashed with the Long Excursion and was consequently not so well attended as it would otherwise have been.

One Museum visit was made, and there were thirteen half-day and three whole-day excursions besides the longer excursions at Easter, Whitsuntide and the Long Excursion, which latter had to be held rather earlier than usual.

The following is a list of the dates, localities, and directors :

DATE.	PLACE.	DIRECTORS.
March 11	British Museum (S.K.)	The President and Dr. C. W. Andrews.
March 18	Zoological Society's Gardens	Dr. P. Chalmers Mitchell, M.A., F.L.S.
March 25	Shooter's Hill, Blackheath, and Lewisham	A. E. Salter, D.Sc., F.G.S., and A. C. Young, F.C.S.
April 1	Gerrard's Cross	R. C. Sikes.
April 8	Welwyn and Harmer Green	A. E. Salter, D.Sc., F.G.S.
April 15	Flitwick and Silsoe	J. Hopkinson, F.L.S., F.G.S., and J. Saunders, A.L.S.
April 21 to 26 (Easter)	Grantham and Louth	Prof. P. F. Kendall, F.G.S., Henry Preston, F.G.S., Rev. W. Lower Carter, M.A., F.G.S., Rev. E. Nelson, M.A.
May 6	Woldingham	W. Whitaker, B.A., F.R.S., F.G.S., and N. F. Robarts, F.G.S.
May 13	Reading and Caversham	H. W. Monckton, F.L.S., F.G.S., and O. A. Shrubsole, F.G.S.
May 20	Erith and Crayford	A. L. Leach.
May 27	Bedford	H. B. Woodward, F.R.S., F.G.S.
June 13	Chilterns	H. B. Woodward, F.R.S., F.G.S., and R. S. Herries, M.A., V.P.G.S.
June 10 to 13 (Whitsuntide)	Isle of Thanet	W. Whitaker, B.A., F.R.S., F.G.S., and A. W. Rowe, M.B., F.G.S.
June 24	Redhill and Reigate	W. P. D. Stebbing, F.G.S.
July 1	Marlow	L. Treacher, F.G.S., and H. J. Osborne White, F.G.S.
July 15	Bishop's Stortford	Rev. A. Irving, D.Sc., B.A., and Percy A. Irving.
July 22	Lambourn and Berkshire Downs	H. J. Osborne White, F.G.S., and L. Treacher, F.G.S.

DATE.	PLACE.	DIRECTORS.
July 24 to 29 (Long Excursion)	Central Wales	The President, Prof. W. W. Watts, M.A., F.R.S., Herbert Lapworth, F.G.S., William Saunders, B.A., E. H. Davies, B.Sc., F.G.S., Miss G. Elles.
September 2	Chelsfield	J. Russell Larkby.
September 16	Hampstead	Griffith Humphreys.

Detailed reports of these Excursions will be found in the PROCEEDINGS.

The loss to the Association through guaranteeing cheap tickets only amounted to £1 13s., and it is considered that the advantages of this system to the members far outweigh the expense.

The Excursion Secretaries responsible for the conduct of the Excursions during the year have been: Miss Foley, Messrs. R. S. Herries, H. Kidner, T. W. Reader, A. E. Salter, W. P. D. Stebbing, A. H. Williams, G. W. Young, and A. C. Young.

Thanks are due to the Directors of the Excursions and also to the following for assistance and hospitality: Dr Chalmers Mitchell at the Zoological Society's Gardens, Messrs. H. and G. Taylor at Lewisham, Mr. Probyn Godson at Shooter's Hill, the Curators of Reading Museum, Mr. John Barker at Bishop's Stortford, the Curator of Newbury Museum, Mrs. Smyth, the Louth Natural History Society and the directors of the Great Northern Railway at Louth. Miss Monkton at Reculvers, and Messrs. W. Cozens, A. Hammond, S. Harvey, and Dr. Channing Pearce at the Isle of Thanet, Mr. E. A. Mayhew and the Express Dairy Co. at Hampstead.

The changes in the House List are not numerous. Dr. A. Smith Woodward, having completed the usual term of office, now retires from the Presidency. The Association has prospered under his guidance, and he has fully earned the thanks of the members by the zeal and ability with which he has discharged his presidential duties. He has also contributed to the PROCEEDINGS a most interesting address which should be the means of stimulating interest in the scientific study of fossils. Mr. L. L. Belinfante, Prof. C. G. Cullis, Mr. J. Allen Howe, and Dr. A. W. Rowe retire from the Council. Thanks are due to all of these for their assistance in carrying on the work of the Association. The names of those suggested by the Council to fill the vacant offices are set out on the ballot paper.

The President called attention to the fact that the Report contained an important proposal regarding the Library. He asked that some member would propose and another second the adoption of the report, when the matter would be open to discussion. Mr.

Walcot Gibson thereupon proposed and Mr. M. A. C. Hinton seconded, "That the Annual Report just read be adopted as the Annual Report of the Association for the year 1905, including the Statement of Account." After some discussion relating to the Council's proposal in regard to the Library, the proposer and seconder consented to the amendment of the motion by the addition of the words, "on the understanding that no action be taken in regard to the Library as suggested in the Report until the members shall have been consulted by the issue of a circular and by the summoning of a special meeting." The motion as amended was then put to the meeting and carried.

The scrutineers reported that the following were duly elected as Officers and Council for the ensuing year:—

PRESIDENT :

R. S. Herries, M.A., V.P.G.S.

VICE-PRESIDENTS :

Rev. J. F. Blake, M.A., F.G.S.
H. W. Monckton, V.P.L.S., Tr.G.S.
Capt. A. W. Stiffe, F.G.S.
A. Smith Woodward, LL.D., F.R.S.

TREASURER :

R. Holland.

SECRETARIES :

Percy Emary, F.G.S.
A. C. Young, F.C.S.

EDITOR :

A. E. Salter, D.Sc., F.G.S.

LIBRARIAN :

Prof. E. J. Garwood, M.A., F.G.S.

TWELVE OTHER MEMBERS OF COUNCIL :

H. A. Allen, F.G.S.
C. W. Andrews, D.Sc., F.R.S.
G. E. Dibley, F.G.S.
John S. Flett, M.A., M.B., D.Sc., F.G.S.
Upfield Green, F.G.S.
Miss M. Healey.
F. L. Kitchin, M.A., Ph.D., F.G.S.
E. T. Newton, F.R.S., F.G.S.
Miss E. Pearse, B.Sc.
T. W. Reader, F.G.S.
W. P. D. Stebbing, F.G.S.
G. W. Young, F.G.S.

The best thanks of the Association were then voted to the Officers and Members of the Council retiring from office, to the Auditors, and to the Scrutineers.

The President then delivered the Annual Address, entitled, "The Study of Fossil Fishes."

On the motion of Dr. Henry Woodward, seconded by Dr. J. J. Harris Teall, it was unanimously resolved that the President's address be printed in full.

This terminated the Annual Meeting.

THE STUDY OF FOSSIL FISHES.

BY A. SMITH WOODWARD, LL.D., F.R.S.

(Being the Presidential Address delivered 2nd February, 1906.)

WHEN addressing the Association last year, I alluded to the inadequate statement of general principles and the preponderance of disconnected facts in most of the elementary books which students of fossils have to consult. On the present occasion I wish to emphasise the importance of a clear grasp of general principles to those who are no longer beginners in our Science, but are attempting to enlarge its boundaries. After a little practice with the eye, it is quite easy to detect the essential points of resemblance and difference between fossils when they are directly compared; it is equally easy to describe these distinctive features in the terms of a conventional formula. When, however, as so often happens, the "research" ends with the description, I fear its tendency is to hinder rather than to advance knowledge, by increasing the undigested mass of material which has been so unskilfully collected that it is of very little use. It is astonishing how many obvious facts can be missed in the description of a fossil when the problems on which that fossil should shed light are ignored or misunderstood. Indeed, the only research of a really satisfactory character is that which is guided by a judicious use of the scientific imagination.

The discovery of general principles in the study of fossils is, of course, much hampered by the imperfection of the geological record. As every geologist is aware, we are dependent for our knowledge of the life of past ages on a few isolated episodes which have been locally preserved. There is no continuous history of the life of long periods in the rocks of any region that has hitherto been well explored. Cessations in the deposit of sediment, the recurrence of unfavourable conditions, and extensive migrations, among other causes, have all contributed to this result. An increasing acquaintance with scattered episodes in the secular development of life, however, tends to reveal its main outlines; and if we are unable to discover the actual facts we can at least arrive at an approximation to them which serves all immediate purposes. If we can determine the "fashion," so to speak, which prevailed during each successive period in the geological history of a race of animals, we are able to distinguish between those changes in anatomical structure which led to stagnation or extinction, and those which were necessary for evolution to a higher plane. An acquaintance with the precise links between one grade and the next is not of supreme importance.

To make my subject intelligible it is necessary to give some concrete illustrations, and I therefore propose to refer to the study of fossil fishes. For many years I have had unusual opportunities for pursuing the geological history of fishes, and I am convinced that we are already able to recognise some very definite principles underlying it.

THE DAWN OF THE SKELETON.

The earliest remains of fish-like animals satisfactory enough for discussion are those from the Upper Silurian rocks, both of Europe and North America. They suggest that long before the latter part of the Silurian period fishes had already become a flourishing and varied race, but could not be preserved among fossils because they had not acquired a hard skeleton. The Upper Silurian fossils show how this skeleton first began, and, if we may assume that the order in which the different kinds of hard parts successively predominate is the order in which they evolved, it is easy to perceive how they gradually arose. Fortunately all the phenomena can be traced in one compact group of lowly fish-like animals, the Ostracodermi or Ostracophori, which are so readily distinguished from the fishes proper that there is no risk of confounding with them members of any other line of descent.

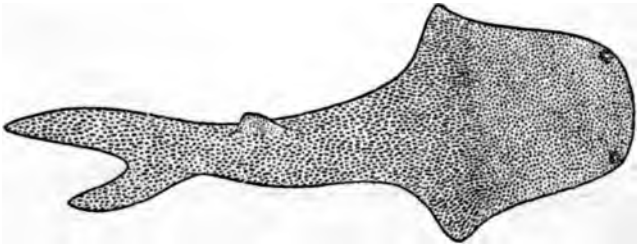

FIG. 1.—*Thelodus scoticus*, Traquair; head seen from above, the tail twisted to show dorsal fin and heterocercal tail mainly in side-view, about one-half nat. size.—Upper Silurian; Lanarkshire. To illustrate the most primitive skeleton of separate skin-tubercles. [After Traquair.]

From numerous well-preserved specimens it is clear that the hard skeletal parts of the Ostracoderms were confined exclusively to the skin; and in most of the earliest representatives of the group these hardenings are merely scattered granules or tubercles of limy matter which form a flexible external armour. It is true that each tubercle is beautifully fashioned, with a definite internal structure round a papilla of the skin, like a tubercle from the shagreen of a modern shark; but the armour is essentially a scattered deposit or segregation of superfluous mineral matter in the normally soft tissue, suggesting that the Ostracoderms towards the end of their race had experienced precisely the same affliction as that now experienced by some of the highest mammals in the latter part of their individual life, namely, a kind of "gout." Myriads of the isolated skin-tubercles of *Thelodus* occur in the Upper Ludlow bone-bed, while numerous nearly complete specimens both of this fish (Fig. 1) and *Lanarkia* have been found in the contemporaneous and somewhat later rocks in Lanarkshire. There is, indeed, no doubt that the granular armour was the "fashionable" fish-skeleton of Upper Silurian time.

It soon became usual, however, for the skin-tubercles to fuse together into groups, and in the earliest Devonian faunas the most common Ostracoderms are those like *Cephalaspis* and *Pteraspis*. The first of these (Fig. 2) is especially instructive as showing how the tubercles became plates, and how the shape of these plates depended on the nature of the underlying parts of the body. In the head-armour of *Cephalaspis* a few regularly spaced tubercles grew larger than the others, and each of these became a centre of attraction with which the immediately surrounding tubercles coalesced, by the thickening of their base, to form polygonal plates. Where the underlying soft parts were not in constant motion these polygonal plates fused again into a continuous shield; while in the roof of parts, such as the presumed gill-chambers, where flexibility was needed, the plates remained as a loose mosaic, which is often lost in the fossils. In the roof of the brain-case, where there would doubtless be only membrane beneath the skin, the internal thickening of the coalesced plates proceeded so far downwards as to receive an impression of the pineal organ of the brain. Round the body the tubercles fused by a similar basal thickening into rings of scales corresponding with the underlying successive plates of muscle.

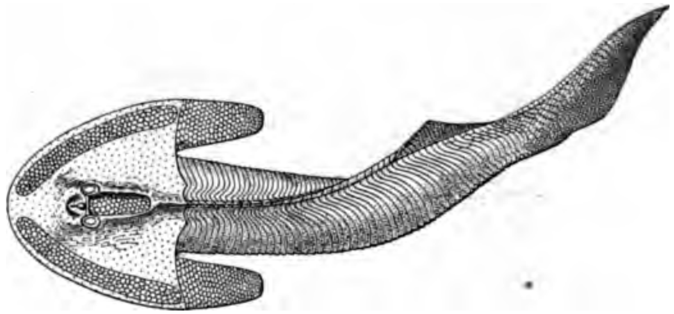

FIG. 2.—*Cephalaspis murchisoni*, Egerton; head seen from above, the tail twisted to show dorsal fin and heterocercal tail mainly in side-view, about one-half nat. size.—Lower Old Red Sandstone Passage Beds; Ledbury, Herefordshire. To illustrate a primitive skin-armour in which the tubercles are fused into small plates, correlated in shape and distribution with the underlying soft parts.

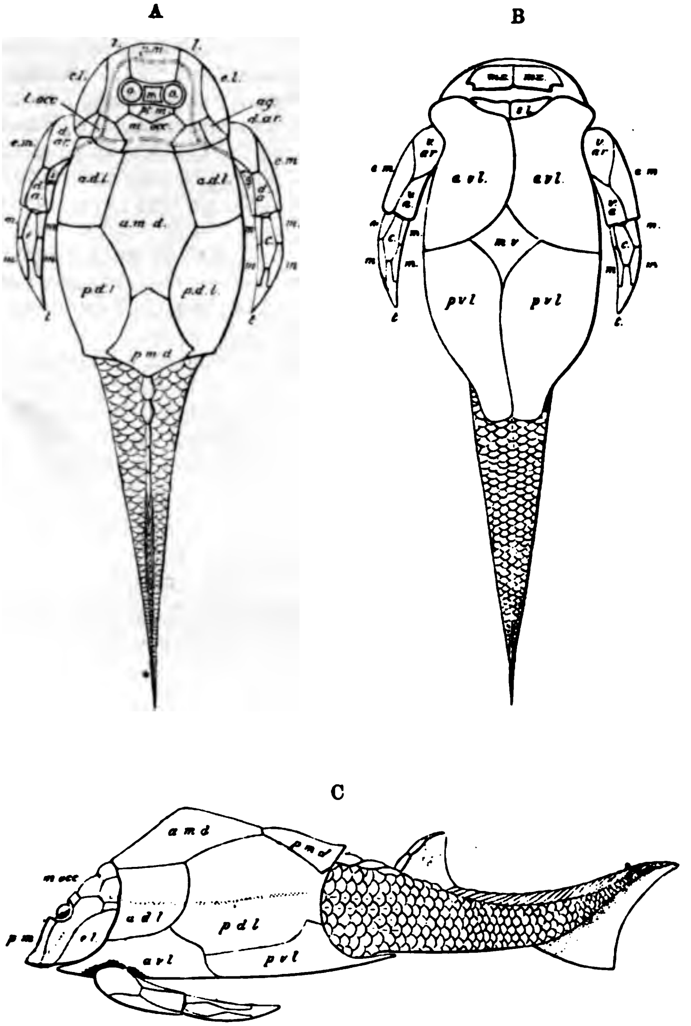

FIG. 3.—*Pterichthys milleri*, Agassiz; dorsal (A), ventral (B), and left lateral (C) aspects, about one-half nat. size.—Middle Old Red Sandstone; N. Scotland ("Lake Orcadie"). To illustrate a primitive skin-armour having the tubercles fused into overlapping plates, which apparently owe their symmetry to incipient coalescence along the course of the slime-canals, not to the shape of underlying soft parts. [After Traquair.] *M. occ.*, median occipital; *l. occ.*, lateral occipital; *ag.*, angular; *pt.m.*, post-median; *p.m.*, pre-median; *l.*, lateral; *e. l.*, extra-lateral; *m.*, median; *o.*, ocular; *mx.*, maxilla; *s. l.*, semilunar; *a. m. d.*, anterior median dorsal; *p. m. d.*, posterior median dorsal; *a. d. l.*, anterior dorso-lateral; *p. d. l.*, posterior dorso-lateral; *a. v. l.*, anterior ventro-lateral; *p. v. l.*, posterior ventro-lateral; *m. v.*, median ventral; *d. ar.*, dorsal articular; *v. ar.*, ventral articular; *e. m.*, external marginal; *i. m.*, internal marginal; *d. a.*, dorsal anconeal; *v. a.*, ventral anconeal; *c. c.*, centrals of lower limb; *m. m. m. m.*, marginals of lower limb; *t.*, terminal of lower limb.

and in all later members of the group the intermediate "spines" dwindled to insignificance (*Mesacanthus*, Fig. 4B) or disappeared (*Acanthodes*, Figs. 4C, 4D), so that only the two normal pairs of fins remained. The fixation and stiffening of these fins, however, were so completely unsuited for further elaboration while they depended solely on skin-structures, that the Acanthodian fishes gradually declined towards insignificance and extinction. They lost their graceful fusiform proportions; some unwieldy and overgrown species became round-bodied grovellers in the mud of Carboniferous seas and estuaries (*Gyracanthus*), while the latest members of the race, which did not increase much in size, became almost eel-shaped before they died out in the Permian period (*Acanthodes*, Fig. 4D). All races which do not progress tend to become represented by eel-shaped species in their latter days, and the Acanthodians formed no exception to the rule.

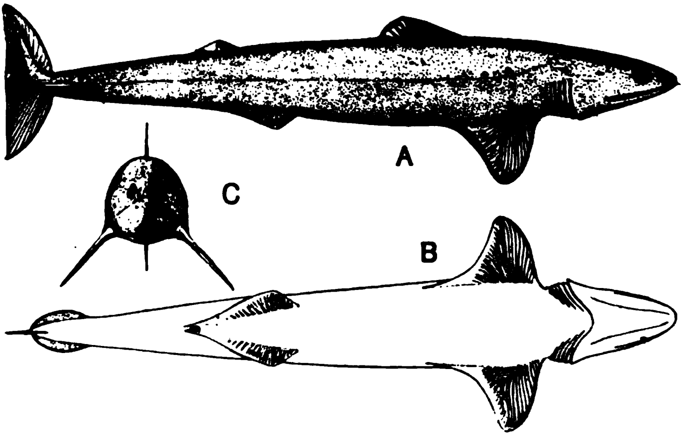

Fig. 5.—*Cladoselache fyleri*, Newberry; right side-view (A), lower view (B), and front view (C), about one-seventh nat. size.—Upper Devonian; Ohio, U.S.A. A long-bodied late survivor of a group of sharks related to the Acanthodians, illustrating the simplest kind of paddle-fins, which are supported by nearly parallel bars of internal cartilage. [After B. Dean.]

PAIRED FINS AS PADDLES.

It is, of course, possible that the fins of the Acanthodians were stiffened by some kind of internal cartilage which was never hard enough for fossilisation; but this seems improbable, because even the stout arch to which the pectoral fins are fixed is shown by microscopical examination to have been entirely a skin-structure, and does not appear to have ensheathed any internal cartilage. There must, however, have been some primitive allies of the Acanthodians with their pairs of fins reduced to the normal two, in which the stiffening was attained by internal rods of cartilage instead of mere skin-structures ; for a long-bodied (and thus senile) survivor of this allied tribe occurs in the Upper Devonian of Ohio, U.S.A. (*Cladoselache*, Fig. 5). Here the fin-flaps are strengthened inside by a row of simple parallel bars of cartilage, which exhibit a tendency to be squeezed together. The early fishes which had reached this stage were prepared for further advance. Those which failed to make any progress in their skin-skeleton experienced very slight changes in their whole anatomy, and gradually passed into the modern sharks and skates. Those in which the skin-skeleton always remained extensive, and soon took the form of symmetrically-arranged bony plates and scales, rapidly became developed into the higher fishes which swarm to-day.

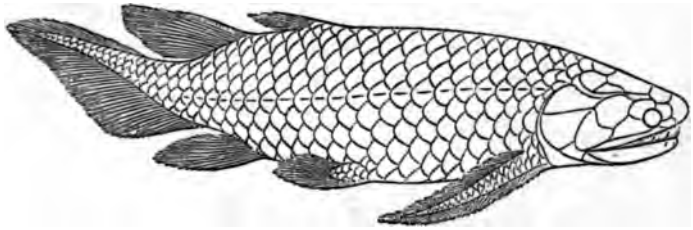

FIG. 6.—*Holoptychius flemingi*, Agassiz ; right side-view, one-eighth nat. size.—Upper Old Red Sandstone, Dura Den, Fifeshire. Showing extreme development of paired fins as paddles, the scaly lobe stiffened by internal cartilages and fringed with rays or fibres in the skin. [After Traquair.]

Fin-flaps stiffened by internal rods of cartilage are essentially paddles, and could be used for crawling in the mud as well as for ordinary swimming in water. It is therefore interesting to observe that during the Middle and Upper Devonian periods, when four-legged lung-breathers must have been just beginning to appear on the land, nearly all the highest fishes had their fins in the shape of paddles. It seems as if at that time there was a general tendency for the fashionable and most advanced fishes to become crawlers rather than swimmers ; and there cannot be much doubt that the known Crossopterygii, or "fringe-finned ganoids," as these fishes are commonly termed, are the unsuccessful survivors of the race which originally produced the earliest crawling lung-breathers or Labyrinthodonts. No intermediate forms have hitherto been discovered, while the links are still wanting between the simple paddle of the fish and the five-toed or four-toed limb of the Labyrinthodont, but the Devonian and some later Crossopterygii are the only fishes which agree with the Labyrinthodonts in (i) the arrangement of their external head-bones ; (ii) the complexity of their tooth-structure ; (iii) the possession of vomerine tusks; (iv) the frequent presence of a pineal foramen in the skull; and (vi) the common occurrence of sclerotic plates round the eye. These resemblances can scarcely be accidental, especially considering the period at which they occur; and it is one of the problems of Palæontology to determine the exact relationships between the paddle-finned fishes and the lung-breathers by the discovery of perhaps Lower Devonian links.

As fishes, the Crossopterygii were obviously not a success, for they could never be active swimmers, and before the close of the Palæozoic epoch most of them had become extinct. The only widely-spread family during the Mesozoic epoch was that of the Cœlacanthidæ (*Undina*, Fig. 7), which became degenerate through having lost some of its head-bones and most of its tail; while the sole survivors at the present day are the eel-shaped *Polypterus* and *Calamoichthys* found in the freshwaters of Africa. The Cœlacanthidæ are often quoted as one of the best illustrations of a "persistent type," for they scarcely changed between the Lower Carboniferous and the Upper Chalk. They are, indeed, like most persistent types, organisms in which structural changes took place in the wrong order—not in the order which ensured advancement.

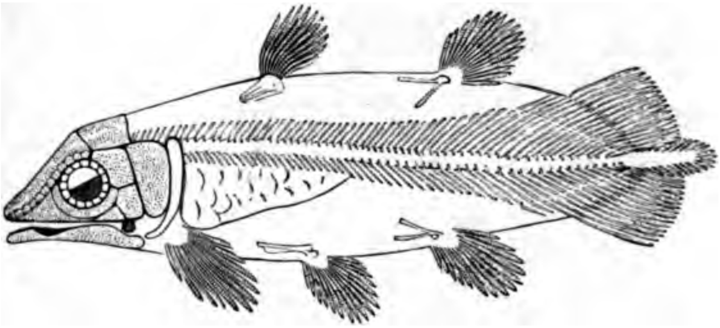

FIG. 7.—*Undina (Holophagus) gulo*, Egerton; left side-view, about one-seventh nat. size.—Lower Lias, Lyme Regis. A paddle-finned fish showing fusion and loss of external head-bones and degeneration of tail, preventing further development in any direction. [From Brit. Mus. Catal. Foss. Fishes.]

DOUBLE BREATHERS.

Another instance of the evolution of structural characters in a wrong sequence is afforded by the Dipnoi, which breathe both by gills and by a modified air-bladder (almost a lung), and are intermediate in many respects between fishes (or gill-breathers) and land animals (or lung-breathers). They are also paddle-finned, and flourished exceedingly in association with the Crosso

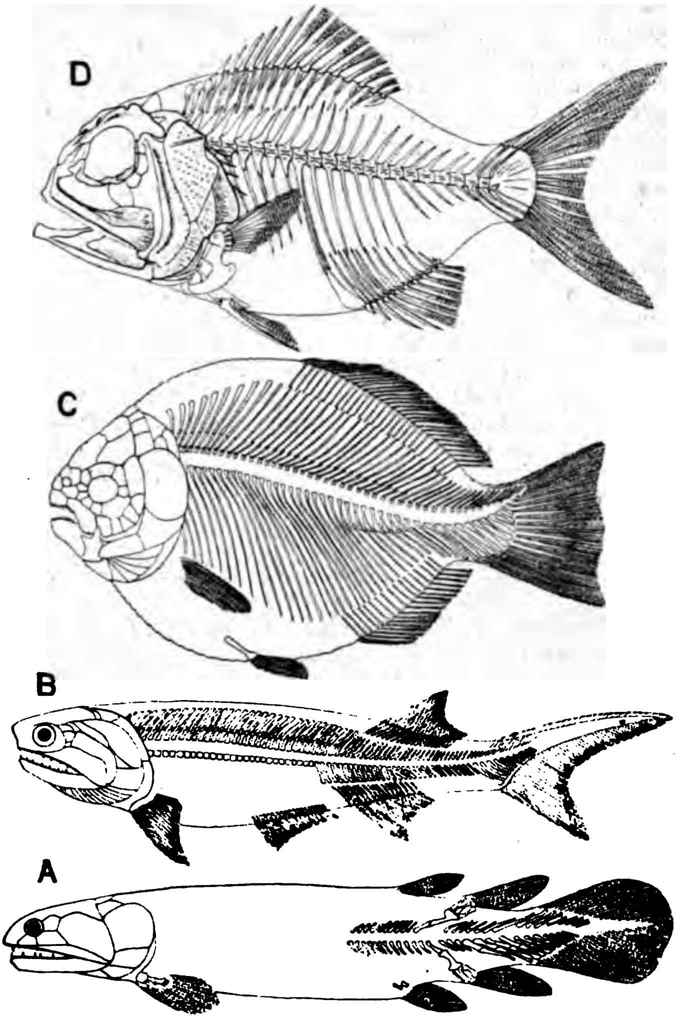

FIG. 8.—DIAGRAM ILLUSTRATING GRADES IN THE EVOLUTION OF BONY FISHES.—A. Paddle-finned fish (Rhizodont Crossopterygian) characteristic of the Middle and Upper Old Red Sandstone periods, internal skeleton only partially shown in drawing; *tendency* towards shortening lobes of fins and simplifying their internal supports. B. Ray-finned fish (Palæoniscid) characteristic of the Carboniferous and Permian periods, showing the extended pelvic fin with numerous supports, the dorsal and anal fins with supports fewer than rays, and the caudal fin heterocercal; *tendency* towards shortening upper lobe of tail, and towards equality in number between rays and their supports in the other median fins. C. Ray-finned fish (*Dapedius*) characteristic of the Triassic and Jurassic periods, showing short-based pelvic fin with one large support, the dorsal and anal fins having a separate support for each ray, and the caudal fin almost homocercal; *tendency* towards acquisition of bony vertebræ and ossification of the cartilaginous skull. D. Modern ray-finned bony fish (*Hoplopteryx*) characteristic of the Upper Cretaceous and Tertiary periods, showing premaxilla below maxilla, completed internal skeleton, pelvic fins far forwards, and some spinous fin-rays; *tendency* towards extreme development of ear-capsules, supra-occipital bone, and premaxilla, besides a fixed number of spinous fin-rays and the forward position of the pelvic fins.

pterygii from the Middle Devonian to the Upper Carboniferous period. In having the fundamental part of the upper jaw fused with the skull instead of loosely suspended from it, the Dipnoi agree more closely with the land animals than do the Crossopterygii; but before this feature had been acquired, the roof-bones of the skull had sub-divided into smaller plates, such as could not have changed into the skull-bones of an ordinary Labyrinthodont, while the teeth had curiously clustered into one pair of plates in the mandible, into two pairs in the upper jaw, so that they could never have produced the Labyrinthodont dentition. The essential change in the Dipnoan skeleton which led towards the land-animals thus occurred too late, after other changes had rendered advance impossible. The result was that with the dawn of the Triassic period the Dipnoi made their nearest possible approach to the higher grade of life in the genus *Ceratodus*, which still survives almost unchanged in the rivers of Queensland; while the latest members of the group degenerated to mere eel-shaped animals (*Lepidosiren* and *Protopterus*), which live in the fresh-waters of South America and Africa.

THE BEGINNING OF EFFECTIVE FINS.

Fishes began to be really successful as soon as the internal cartilages of each fin became reduced to an effective basal support for an expanse of membrane, which was stiffened by flexible skin-fibres. The latter eventually formed "fin-rays," and articulated with the basal pieces when the cartilage was replaced by bone. Thus arose the best form of appendage both for balancing the body and for progression in water.

Fins of this kind are first met with in the Chondrostei ("gristle-boned") which characterised the Carboniferous and Permian periods, when the Crossopterygii were distinctly on the wane. Some of the early Crossopterygians with short-lobed paired fins (Fig. 8A), closely approached this later and higher grade; but it is doubtful whether they ever attained it, because each of their fins had a constricted base, whereas in the Chondrosteans the hinder or pelvic pair of fins had a long base-line, and it is difficult to understand how the latter primitive-looking state can have been derived from the former paddle-like modification. Moreover, one of the Chondrosteans (*Cheirolepis*) occurs sometimes in the Middle and Upper Devonian, both of Europe and America, so that it is not unlikely common ancestors will some day be found lower in the geological series.

The typical Chondrosteans of the Carboniferous and Permian periods are the Palæoniscidæ and Platysomidæ. The former (*Palæoniscus*, Fig. 9) were rapacious fishes, and a few of them survived with little change until Upper Jurassic times. The latter (*Platysomus*, Fig. 10) had a small mouth, with blunt teeth for crushing, and tended to become deep-bodied in shape. They were extinct before the end of the Permian period.

In all these fishes (Fig. 8B) the slender, tapering hinder end of the body curves upwards on the "heterocercal" plan, so that the tail-fin is confined to the lower border, while the skeleton of the other median fins has an unfinished aspect, because the fin-rays are not directly correlated with their basal supports, but are always more numerous than the latter. So long as this arrangement persisted, no real progress could be made in the rest of the skeleton, and degeneration in certain directions soon began. Some of the small Chondrosteans of the Triassic, Rhætic, and Liassic periods became eel-shaped (Belonorhynchidæ) and then died out. Others, which were practically naked Palæoniscidæ in the Liassic period (*Chondrosteus*), gradually lost their normal head-bones, sometimes grew to unwieldy proportions, and finally became the sturgeons of the present day.

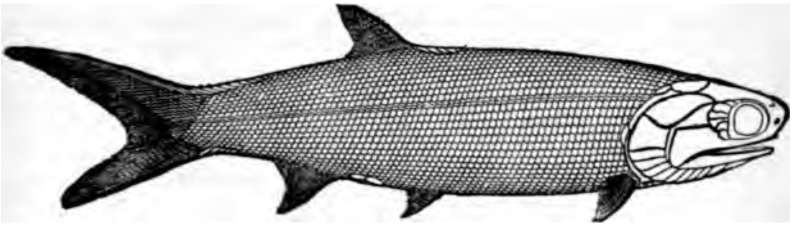

FIG. 9.—*Palæoniscus macropomus*, Agassiz; right side-view, about one-half nat. size.—Upper Permian; Thuringia. Illustrating heterocercal tail and numerous delicate fin-rays of a Chondrostean fish. [After Traquair.]

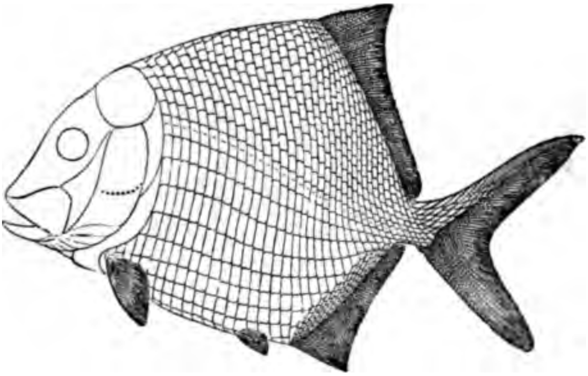

FIG. 10.—*Platysomus gibbosus*, Agassiz; left side-view, about one-quarter nat. size.—Upper Permian; Durham. A deep-bodied Chondrostean fish, compare Fig. 9. [After Traquair.]

THE COMPLETION OF THE FINS.

The shortening of the upper lobe of the tail so that the tail-fin becomes a flexible fan-shaped expansion at the blunt end of the body, and the definite provision of one support for each separate ray in the other median fins, are first noticed in one rare fish (*Acentrophorus*) from the Upper Permian of Europe. This effective completion of the fins, however, must have occurred in a great group of fishes before the close of the Permian period, because it characterised numerous genera in the Trias and all the most fashionable members of the Rhætic and Jurassic faunas (Fig. 8c). It was an important advance, because so soon as it happened ray-finned fishes began for the first time to exhibit an extensive hardening of their internal skeleton and the acquisition of vertebræ. In fact, the interest of these Protospondyli ("first vertebræ"), as they have been termed, consists in the very varied conditions of the internal skeleton which they provide for study.

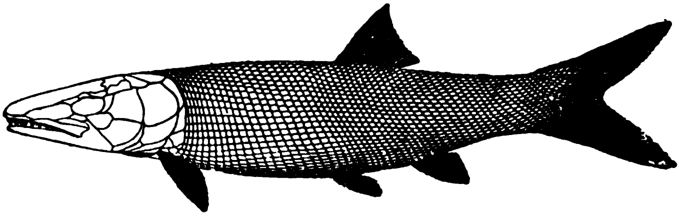

FIG. 11.—*Eugnathus orthostomus*, Agassiz; left side-view, about one-seventh nat. size.—Lower Lias; Lyme Regis. A Protospondylic fish showing a nearly homocercal tail and fin-rays of the modern type. [From Brit. Mus. Catal. Foss. Fishes.]

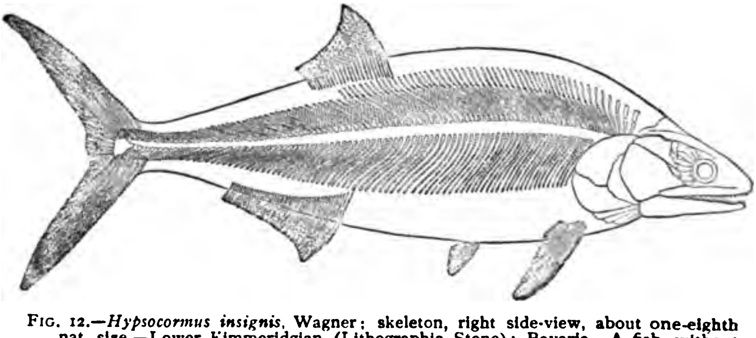

FIG. 12.—*Hypsocormus insignis*, Wagner; skeleton, right side-view, about one-eighth nat. size.—Lower Kimmeridgian (Lithographic Stone); Bavaria. A fish without bony vertebræ tending to become a powerful swimmer and use its pointed snout like a sword-fish, gaining the requisite strength for the tail by extreme multiplication of the vertebral arches, and the fan-shaped expansion of one hæmal spine. [From Brit. Mus. Catal. Foss. Fishes.]

Like the Chondrostei already mentioned, the Protospondyli soon began to exhibit development in two directions. Fishes like ***Eugnathus*** (Fig. 11) formed a rapacious race, with a remarkable strengthening of the internal skeleton, sometimes with complete vertebræ. More sluggish fishes beginning like *Lepidotus* were followed by blunt-toothed races, which either passed into long-bodied animals (Macrosemiidæ), or lost some of their external bones before the internal skeleton had begun to progress, and so degenerated into the deep-bodied Pycnodonts. One rapacious family (Pachycormidæ) is especially interesting, because some of its members resembled in outward form the modern sword-fishes. Not having a completed vertebral column on which the powerful tail could work, the necessary mechanical result was obtained by the multiplication and close overlapping of the long and slender vertebral arches (*Hypsocormus*, Fig. 12). The surviving representatives of the Protospondyli and their allies, confined to the freshwaters of North America (*Amia* and *Lepidosteus*), exhibit the usual long-bodied shape of decrepit derelicts.

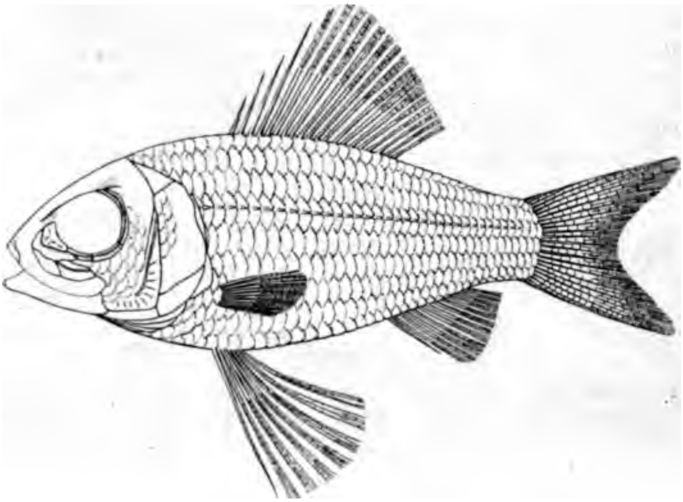

FIG. 13.—*Ctenothrissa vexillifer*, Pictet; left side-view, slightly enlarged.—Upper Cretaceous; Mount Lebanon. A herring-like fish with scales serrated and pelvic fins far forwards.

THE COMPLETION OF THE INTERNAL SKELETON.

Although, as soon as the fins had been completed, the large majority of the ray-finned fishes began gradually to elaborate their internal skeleton in different directions, one precocious group evidently completed its vertebral column at once. This race, including such genera as *Pholidophorus* and *Leptolepis*, seems to have temporarily exhausted itself in the effort, for it always occupied a secondary place in the fish-faunas until the beginning of the Cretaceous period, when it rapidly multiplied, became fashionable, and replaced the Protospondyli. Thus arose the modern fishes of the same grade as the herring and salmon, provided not only with a complete vertebral column, but also with a simplified lower jaw, which consists only of two pieces on each side (without the splenial bone which forms so conspicuous a feature of the earlier fishes). They are named Isospondyli ("equal vertebræ"), in allusion to the circumstance that the vertebræ are separate throughout, not fused together or modified behind the head, as in some allied but higher fishes.

The Isospondyli, having a completely bony internal skeleton as well as completed fins, admitted of many more variations than any of their fore-runners. The typical fish-head now began, for the first time in its history, to exhibit essential changes. The supraoccipital bone often grew upwards to project on the roof, and thrust outwards the now well-ossified and enlarged ear-capsules (Chirocentridæ); while the premaxilla sometimes extended backwards to slip beneath the maxilla and exclude the latter from the margin of the upper jaw (Enchodontidæ). The pelvic fins in a few fishes were now displaced forwards, so that their supports even touched the bones bearing the pectoral fins (Ctenothrissidæ, Fig. 13). Still more interesting, the bones of the gill-cover began for the first time to develop spines (Enchodontidæ, Fig. 14).

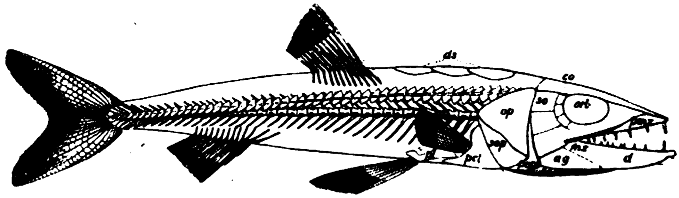

FIG. 14.—***Eurypholis boissieri***, Pictet; right side-view, one-half nat. size.—Upper Cretaceous; Mount Lebanon. Showing premaxilla (*pmx.*) partly replacing maxilla (*mx.*) in mouth; a spine on preoperculum (*pop.*); and pelvic fins (*pl.*) far forwards. Other letters:—*Ag.*, angular; *co.*, circumorbitals; *d.*, dentary; *d. s.*, dorsal scutes; *op.*, operculum; *orb.*, orbit; *pcl.*, postclavicular plate; *so.*, suborbitals; *sop.*, suboperculum. [From Brit. Mus. Catal. Foss. Fishes.]

SPINES AND SPINY FINS.

Among fishes, as among other animals, spines characterise only the latest representatives of the class. When the skeleton is well ossified, races which have reached or just passed their prime tend to acquire more skeletal matter than they actually need, and the surplus is then arranged as spines and bosses, usually in a symmetrical manner. In the case of fishes, some of the fin-rays become hardened, and spines arise chiefly on the cheeks and gill-covers. The Acanthopterygii ("spine-finned") are thus the highest and latest fishes of all, though they sometimes eventually descend from their high estate by degeneration. They exhibit all the peculiar changes in the skull, upper jaw, and pelvic fins noticed as first appearing in a variable manner in the Cretaceous Isospondyli. They also differ from all the earlier races of fishes in the common numerical fixity of their vertebræ and fin-rays. There are whole families in which the number of vertebræ never varies, and there are large genera in which all the species have the same definite number of spinous fin-rays.

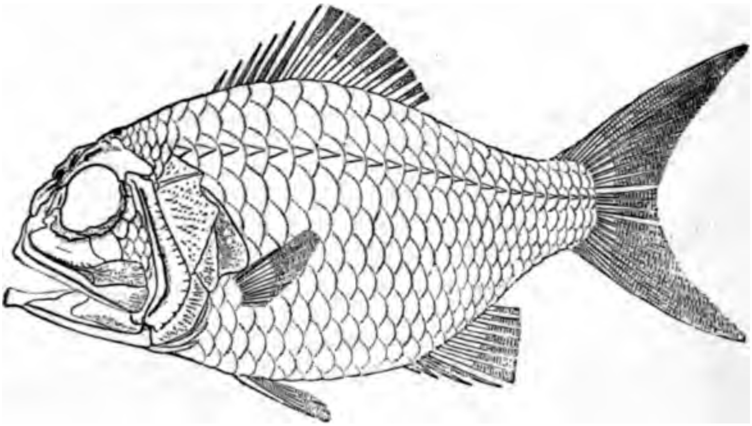

Fig. 15.—*Hoplopteryx lewesiensis*, Mantell; left side-view, one-third nat. size.—English Chalk. Forerunner of the dominant modern spiny-finned fish.

The spiny-finned fishes began by Berycoids and possibly Scombroids in the Chalk, closely resembling but not identical with genera living at the present day. The so-called *Beryx* of the Chalk (*Hoplopteryx*, Fig. 15) is now proved to be very different from the existing genus bearing that name. By the Eocene period, however, nearly all the modern groups of Acanthopterygii had become completely separated and developed, and their sudden appearance is as mysterious as that of the early Eocene Mammalia.

CONCLUSION.

The study of fossil fishes, as now pursued, is thus an attempt to solve the following fundamental problems :

1. The nature and order of the successive advances in

anatomical structure which have suddenly infused new life into the class—the "expression points," as Cope termed them.

2. The new possibilities of development which arose with each successive "expression point."

3. The direction of the various abortive lines of advance and degeneration in each successively higher grade.

4. A correlation of all these results to discover general principles for comparison with those deduced from the study of other groups of animals.

When pursued with aims of this kind, Palæontology becomes a Science, and fossils are no longer mere time-markers for the geologist who unearths them and fixes their stratigraphical position. The results of such a study, indeed, have an important bearing on the most fundamental questions concerning "living" matter as contrasted with "dead" matter; for, in my opinion, we are much more likely to approach some explanation of life by studying the secular development of whole races than by examining the vital processes of individuals or by comparing the members of a single contemporaneous fauna.

Fig. 1

Fig. 2

OSTRACODAL LIMESTONE—UPPER PURBECK,
DURLSTON BAY, DORSET.

F. C. photo-micr.

NOTE ON AN OSTRACODAL LIMESTONE FROM DURLSTON BAY, DORSET.

FREDERICK CHAPMAN, A.L.S., F.R.M.S., Palæontologist to the National Museum, Melbourne.

[*Read March 2nd, 1906.*]

INTRODUCTORY REMARKS.

HE rock described below, obtained by the writer a few years since from Durlston Bay whilst in search of microzoa in fossiliferous beds exposed along the English Coast, is a ing example of a limestone which is almost entirely com- ed of the valves of Ostracoda, and its excellent preservation ers it worthy of a detailed description.

Near the top of the Upper Purbeck Series at Durlston Bay, es and thin limestones are abundantly represented. They are lly composed of Ostracoda and freshwater shells of the genera *Unio*, *Cyrena*, and *Cyclas*. Forbes and Bristow's Division *b** specially characterised by the Ostracoda-shales, and our imen came from about the base of this division, or the of Division *c*, of those authors.

DESCRIPTION.

The specimen has an average thickness of 16mm. It esents a portion of a bed of limestone of considerable zontal extent, since it appears as a distinct layer in the cliff- ion. In colour it is a dark bluish grey, stained in places with nite. It approaches the bituminous variety of limestones in ark appearance and inclusion of organic matter. The upper ace is weathered, and shows, scattered over it in countless bers, the concave interiors of valves of Ostracoda belonging he genus *Cypridea*. The plane of bedding in this limestone d is somewhat irregular, and is crossed at various angles by low grooves or elongate depressions, as if caused by the ing of a worm-like organism over the deposit whilst still soft. bones, probably the remains of *Lepidotus minor*, amongst er Purbeck fish, occur sparsely distributed through the rock, appear on the weathered surface as brown, glittering frag- ts. The under surface of the rock is similarly weathered, shows, as a rule, the convex exteriors of the Ostracod valves, here and there a mass of Ostracoda heaped together in the n of an internal cast of the valve of a small species of *Cyrena*, which had been originally filled up by the drifting anisms.

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* *Geol. Surv. Gr. Brit.*, Vertical Section, No. 22.

The Ostracoda all belong to the one genus previously mentioned and comprise the following species, placed in order of their relative abundance:

Cypridea punctata, Forbes sp.
" *posticalis*, Jones.
" *ventrosa*, Jones.

The first-named is by far the commonest form.

MICROSCOPICAL DETAILS.

In thin slices under the microscope the rock is seen to consist of myriads of valves of Ostracoda, closely packed together; the interstitial mud being reduced to a minimum, merely serving to fill up the hollows between the shells. A fair proportion of carapaces with connected valves is present, but the majority are separated valves, often lying packed one within the other, sometimes to the number of five. This feature indicates that the Ostracoda were deposited in shallow pools and were gently drifted to and fro before finally settling down and becoming covered up.

The united valves almost invariably enclose some dark, granular, calcitic mud, whilst slender calcite crystals usually project all round the internal surfaces of the valves. In a few cases this secondary growth of calcite has obliterated the internal boundary of the original shell-surface, the crystals being in optical continuity with the organic part of the shell. This peculiarly interesting structure was first described by Dr. Sorby in his presidential address to the Geological Society in 1879[*] from Portland Oolite specimens, in the following words:

"In the case of the Entomostraca met with in the upper part of the Portland Oolite in Portland, the increase in the size of these small original crystals has given rise to a very curious result. They have often been so much lengthened by the deposition of calcite inside the valves that the shell is many times thicker than it must have been when living. In some of the attached valves the place occupied by the animal is now solid calcite. A filling up with calcite is of course a very common occurrence. The special peculiarity is that the calcite is not in the form of coarse crystals, having no relation to the structure of the shell, but is a perfect continuation of the original minute shell-prisms, so that the whole of the abnormally thickened valves has the mechanical and optical structure characteristic of the living shell."

The shells of the carapace in the Durlston limestone are of a pale horn-brown colour when unaltered, and usually show a fibrous or prismatic structure vertical to the shell-surface. Scattered throughout the limestone there are a few valves perfectly black, probably having been strongly permeated with bitumen. The

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[*] *Quart. Journ. Geol. Soc.*, vol. xxxv, 1879, p. 67.

only other constituents to be seen in this rock under the microscope are occasional pieces of molluscan shells, chiefly bivalves, and clear yellowish-brown fish-bone fragments.

In his presidential address on the structure and origin of limestones Sorby remarks, on p. 79, upon the occurrence of a somewhat similar specimen from the Purbeck Limestone Series. Speaking of this specimen he says:

"Another specimen, no doubt deposited in more tranquil water, contains much fine-grained mud, fewer fragments of large shells, and many Entomostraca."

A second brief record of a cyprid-limestone, which is apparently from the same horizon as the one here described, has been given by Prof. Rupert Jones in his classical paper on the Purbeck and Wealden Entomostraca.[*] Prof. Jones mentions a specimen —No. 405 (T. R. Jones's collection)—labelled "Durlston Bay. Between Burstone [Burr-stone] and Marble beds. Impure laminated limestone composed of *C. punctata* and broken *Cyclas*. J. C. Mansel-Pleydell, 1884."

In explanation of the relative position of the *Cypridea* beds, it may be as well to note that the Burrstone is the shell-limestone near the base of the Upper Purbeck, whilst the Marble beds are at the top, in the Durlston Bay section.[†]

With regard to the distribution of the *Cypridea* referred to, it is interesting to note that all three species, *C. punctata*, *C. posticalis* and *C. ventrosa* are common to the Upper and Middle Purbeck series. According to Prof. Rupert Jones, *C. purbeckensis* is characteristically abundant in the Upper Purbeck, whilst *C. posticalis* is more abundant in the Middle Purbeck.[‡]

Atlhough Cyprid shales and shelly limestones with Cyprids are common in the Upper Jurassic beds of England, it is not so common to find so pure an ostracodal limestone as that upon which the foregoing remarks have been based.

EXPLANATION OF PLATE.

Fig. 1.—Upper surface of Ostracod-limestone, showing the weathered valves in relief. × 14.

Fig. 2.—Vertical section through Ostracod-limestone. The numerous valves are seen to be partially filled with dark granular, calcitic mud, and to have their internal surfaces lined with crystals of calcite. × 14.

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[*] *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 322.

[†] See Woodward, H. B., *Geol. England and Wales*, 1887, pp. 344, 349.

[‡] Jones, *loc. cit.*, p. 332.

REMARKS ON THE UPPER CHALK OF SURREY.

By A. J. JUKES-BROWNE, B.A., F.G.S.

[*Read March 2nd, 1906.*]

THE Upper Chalk of Surrey has recently acquired special interest because of the discovery that it includes a large part of the zone of *Marsupites*. When I prepared the chapter on the Upper Chalk of this county for the Geological Survey memoir on "The Cretaceous Rocks of Britain," published in 1904, not a single plate of *Marsupites* or *Uintacrinus* had been found, either in Surrey or in the adjoining part of Kent. I began that chapter by stating that "no systematic exploration of the Upper Chalk of Surrey has yet been made," and I could not even be certain that the zone of *Marsupites* came into the western part of the county. As regards the Eastern part of the county, I expressed my belief that this zone was not present in that area and that the Chalk there had suffered greatly from erosion before the deposition of the lowest Eocene beds.

My reason for this opinion was that the thickness of the Upper Chalk in that area, as proved in the boring at Streatham, was less than it is known to be either to the east, north, or west, and, consequently, that, if the zones of the Chalk maintained anything like the thicknesses which they severally possess in Kent, it was not likely that a total thickness of only 623 ft. could bring in the zone of *Marsupites* below Streatham.

Nothing pointed to any great variation in thickness of the zones in these south-eastern counties, so that the inference was a reasonable one, but, nevertheless, it has turned out to be wrong. Not only does the zone of *Marsupites* exist in Surrey, but the systematic exploration of the Upper Chalk which was a desideratum in 1903 has now been ably carried out by Mr. G. W. Young,* who has shown that the *Marsupites* chalk occurs not only in outliers at a distance from the border of the Eocene, but also at so many points along that border that we are warranted in supposing it to have a continuous outcrop from Addington on the east to Ashtead and Epsom on the west. The probability of its further continuance through western Surrey is very great, for its existence there was surmised by Prof. Barrois in 1876,† and his description of the highest Chalk seen near Guildford was quoted in the memoir on Cretaceous Rocks.

It appears, therefore, to be demonstrated that the zone of

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* *Proc. Geol. Assoc.*, vol. xix, p. 188 (1905).

† *Recherches sur le Terr. Cret.*, *Mem. Soc. Geol. Nord.* i (1876), p. 139.

Marsupites does form an integral part of the Upper Chalk of Surrey, and we are at once confronted by the question—how can this be made to accord with the supposed small thickness of that division of the Chalk in East Surrey? I can imagine three possible answers to this question: (1.) The record of the Streatham boring may not be correct and the thickness of the Chalk at the outcrop may be greater than was supposed; (2.) The record of the boring may be correct and the thickness below Streatham may be exceptionally small from local pre-Tertiary erosion; (3.) Some of the Upper Chalk zones may be much thinner than they are in the neighbouring counties.

Mr. Young does not seem to have realised this difficulty, for his discussion of the supposed small thickness of Chalk in East Surrey does not touch the question. He quotes part of a passage from my "Building of the British Isles," but seems to have misunderstood it, for he says that I mentioned no boring south of London between Chatham and East Horsley, whereas I expressly said that the Chalk was thinnest at Streatham, and suggested that a pre-Tertiary uplift "had produced a broad low dome which had its centre on the Surrey side of the Thames."*

Mr. Young argues for a continuous and rapid thinning of the Chalk south of London and for the existence of a local north and south anticline in Tertiary times, but the evidence to which he refers is merely that of the overlap of the Blackheath Beds, which was probably a general southward overlap and overstep along a wide tract or front caused by a contemporary uplift of the Chalk over the Wealden area. I do not desire to discuss this point, but shall keep to that which seems of special interest, namely, the pre-Tertiary thickness of the Chalk, and how it comes to pass that the zone of *Marsupites* is present in Surrey. I propose, therefore, to consider all the evidence that is now available on this point

To begin with the Streatham boring, there is no good reason to doubt the accuracy of the record and, fortunately, samples of Chalk from successive horizons were examined by Mr. W. Hill. I am inclined to think, however, that the base of the Upper Chalk may be somewhat lower down than the plane taken by Messrs. Hill and Whitaker in 1889.† It is stated (p. 228) that a specimen from 460 ft. showed "the peculiar structure of Chalk Rock," but Mr. Hill informs me that by this he meant to say it showed the characters of the Rocky Chalk which occurs in the zone of *Holaster planus* in the south-eastern counties, and the structure of which is similar to that of the Chalk Rock of more western counties.

The next sample examined was from 485 ft., and this is described as "probably the top of the zone of *Terebratulina*

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* *Building of the British Isles*, Ed. ii, p. 291. (1892.)

† See *Geology of London* (*Mem. Geol. Survey*), vol. ii, p. 225.

gracilis in the beginning of the passage to the Chalk Rock." Mr. Hill has kindly re-examined his slide of this Chalk and tells me that it is probably from the very highest part of Middle Chalk, and possibly only just below the base of the *Holaster planus*-zone as defined by us on pp. 138 and 139 of the "Memoir on Cretaceous Rocks." Hence the base of the Upper Chalk may be as low as 480 ft., and as the top of it was found at 241½ ft. the thickness of this division may be 238½ ft. Even so, however, it remains very thin if we are to suppose that it includes even a small part of the *Marsupites*-zone.

In this connection it is noteworthy that the highest 8½ ft. are described as consisting of "flints with little chalk," below which are 11 ft. of "soft white chalk without flints," and then chalk with frequent layers of flints. It seems to me very likely that the highest 8½ ft. really consisted of soft chalk with a few flints, the chalk being so soft and rotten from the water percolating into it from the overlying sands that it went to pieces under the boring tool, which only brought up the flints. It is possible, therefore, that this 8½ ft. represents much more than that thickness of chalk, and that the boring traversed 28 to 30 ft. of the *Uintacrinus* band before entering the zone of *M. cor-anguinum*, but if so the latter cannot have more than half its usual development, for the zones of *Holaster planus* and *M. cor-testudinarium* combined are not likely to be less than 100 ft. thick, and this will leave only 119 ft. for the zone of *M. cor-anguinum*. If, however, the *Marsupites*-zone does not come in under Streatham there will be at least a thickness of 138 ft. assignable to that zone.

Let us next consider the boring at Purley for the East Surrey Waterworks, as recorded by Mr. Whitaker,* and the estimate of thickness which Mr. Young has attempted to make therefrom. Unfortunately Mr. Young's particulars of the boring are not quite correct, and his total is too small. The account published by Mr. Whitaker puts the base of the Chalk at 479 ft. from the surface, and gives the surface level at 215 above O.D. The highest point of Russell Hill to the N.N.W. is 361 ft., so that the difference is 146 ft., which, added to the depth at Purley, makes a total of 625 ft. But there is a distance of half-a-mile between the site of the boring and the top of Russell Hill, and a certain thickness of Chalk must be brought in here by the northerly dip. If we take the dip as only 1 deg. this will bring in 17 ft. in 1,000, and consequently about 44 ft. in half-a-mile. This, added to the 625, gives 669 ft., and even this does not take us to the very top of the Chalk, for Russell Hill is not capped by Thanet Beds, though its summit is probably very few feet below the plane of their base.

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* "Some Surrey Wells" (fourth paper), *Croydon Nat. Hist. and Sci. Soc. Trans.*, p. 7 (1905).

We can hardly be far wrong, however, in taking the full thickness of Chalk below Russell Hill as about 670 ft., and as this is more than the total at Streatham or than the average thickness under London, this evidence favours the view that the thickness along the outcrop of the Chalk is greater than it is under the Eocene to the north. The difference however is not sufficient to explain the presence of the *Marsupites*-zone; allowing 380 ft. for the Lower and Middle Chalk the thickness left for the Upper Chalk will be 290 ft., but of this 40 or 50 ft. must belong to the *Marsupites*-zone and if 100 ft. is assigned to the lower zones, there is left only from 140 to 150 ft. for that of *M. cor-anguinum.*

There might of course be a fault between Russell Hill and the Purley boring with a down-throw to the north of about 100 ft., but this would be making a great assumption, without any evidence to support it. It seems much more probable that some part of the Upper Chalk is unusually thin in Surrey, and since both of the zones of *Holaster planus* and *M. cor-testudinarium* seem to be well developed, it must be the zone of *M. cor-anguinum* which is here so much thinner than usual.

A thickness of 150 ft. is small when compared with the known thickness of this zone elsewhere. Thus on the Kentish coast it is estimated to be 250 ft. thick; in Sussex it has been measured and found to be 242 ft.; near Chatham it must be at least 200 ft., and in South Wilts it is estimated at 240 ft. Moreover at East Horsley, in the very centre of Surrey, a boring made in 1886 proved no less than 817 ft. of chalk,* which seems to give room for a normal thickness of the *M. cor-anguinum*-zone.

Unfortunately the record of the boring at East Horsley does not give sufficient details of the Chalk to enable us to fix the thickness of the Upper and Middle divisions from the account given, for the passage from the one division to the other must occur somewhere in a thickness of 159 ft. which is lumped together as "very hard Chalk." It seems clear, however, that the thickness of the Lower Chalk is 174 ft., and we shall not be far wrong if we put the thickness of the Middle Chalk at 200 ft., and in this way we get a remainder of 443 ft. for the Upper Chalk. Now if we assign (as before) 100 ft. of this to the zones of *Holaster planus* and *M. cor-testudinarium*, and allow 100 ft. at the top for the zone of *Marsupites*, there is 243 ft. left for the zone of *M. cor-anguinum.*

It seems, therefore, nearly certain that whatever may be the cause of the small thickness of Upper Chalk in Eastern Surrey it has ceased to prevail at East Horsley. If, therefore, the real thickness of the zone of *M. cor-anguinum* is only about 150 ft. at Croydon and Purley it has thickened again to its normal amount at Horsley. In other words the tract over which it becomes so

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* See "Some Surrey Wells," by W. Whitaker, *Trans. Croydon Micr. and Sci. Soc.* (1894), p. 137.

thin lies between Horsley and Dartford, a distance of about 30 miles. Any further information about the thickness of the *M. cor-anguinum* Chalk within this area will be useful and interesting, especially with regard to the plane of division between it and the zone of *Marsupites.* There may have been some contemporaneous erosion, such as seems to have occurred at Taplow.

In conclusion it must be clearly understood that the view which is advocated above is merely a surmise, put forward to explain the presence of the zone of *Marsupites,* and adopted solely because it accounts for all the facts without introducing any other difficulty or assumption into the problem.

THE DEVONIAN LIMESTONES OF LUMMATON HILL, NEAR TORQUAY.

By A. J. JUKES-BROWNE, B.A., F.G.S.

(Read March 2nd, 1906).

1. Introduction.

THE quarries on Lummaton Hill, two miles north of Torquay, are well known to all who are interested in the Devonian limestones, and have yielded a larger number of fossils to collectors than any other quarries near Torquay. But although geologists have visited these quarries for the last 50 years or more the earliest description of them which I can find is that written by the Rev. G. F. Whidborne for Davidson's Monograph on British Brachiopoda in 1882.*

Referring to the three contiguous quarries on the eastern side he says, "They are in a mass of dense, crystalline, bluish-grey limestone, with occasional joints, and with hardly any signs of bedding. Fossils occur rarely scattered through them, but are very difficult to extract entire. Occasionally, however, there are local accumulations of corals and sponge-like growths, and at one spot on the top of the third quarry is a small exposure of the rock where the smaller fossils occur in great numbers, and may in many cases be easily detached from the matrix. It is most probable that from this spot most of the so-called Barton fossils were obtained. At the base of the quarry, almost perpendicularly below this, similar fossils occur in numbers, and this would lead to the supposition that the dip is here a great one."

Mr. Whidborne informs me that by "sponge-like growths" he meant Stromatoporoids, but his account gives the impression that only one kind of limestone is to be seen, and that fossils occur in local accumulations. His inference with regard to the dip, however, I believe to be correct.

In his own Monograph on the Devonian Fauna he again refers to the spot from which he obtained so many fossils, and writes: "Most of the Crustacea at Lummaton have occurred in the bed at the top of the quarry, which is apparently little else than a shell-heap and which was probably a local and littoral deposit. This would explain the fact that the Trilobites are almost always found there in a fragmentary condition; for most likely they had decayed and fallen asunder before they reached their place of deposition."†

Mr. Whidborne's observations certainly seem to show that there is a bed or band which is specially rich in small shells,

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* *Supplement to the Devonian Brachiopoda, Pal. Soc.* for 1882, p. 6.
† *Pal. Soc.* for 1888. *Devonian Fauna*, p. 2.

Trilobites and other organisms, but that this is in any sense a littoral deposit I very much doubt. In a subsequent passage, however, he expresses himself in terms with which I can fully agree, thus (p. 180): "Judging from the general facies of the Lummaton fauna it did not inhabit deep water, and was exposed to the action of strong currents and tides." Such conditions would suffice to account for the fragmentary state of the Trilobites.

Mr. Ussher made a few remarks on Lummaton in his paper on "The Devonian Rocks of South Devon,"* observing that "from its massive nature the structure of the Lummaton limestone, as also that of Barton, which I correlate with it, is not apparent. The Brachiopod fauna is in a very restricted space and the rock is there very similar to parts of the Ugbrook Park and other limestone masses on the border-land between the middle and upper Devonian." He also notes that Dr. Kayser correlates the Lummaton shelly limestone with the upper part of the middle Devonian.

In his use of the word "structure" in the passage above quoted I understand Mr. Ussher to mean tectonic structure, and that he was unable to recognise any definite dip or any succession of beds either in these quarries or in those of Barton.

In his later Memoir on the "Geology of Torquay,"† Mr. Ussher describes the Lummaton limestone in the following terms: "The Lummation limestone is bounded by the New Red rocks on the north and west. It is well exposed in the quarries on Lummaton Hill, and consists for the most part of a pale grey or dove-coloured finely-crystalline, massive, coralline limestone in which *Smithia hennahi* is conspicuous. The rock appears to be partly dolomitic in the western quarries. In the large eastern quarry rubbly, broken, shelly limestone occurs in one or two places, extending from the surface at the top of the quarry irregularly downward for a few feet in the more massive rock."

This description does not apply to the southern part of the eastern quarry, and species of *Smithia*, so far as my own experience goes, have only been found in the western part of the north-western quarry. Lastly, recent excavations have shown that shelly limestone occurs at the bottom of the northern quarry as well as at the top, confirming the statement made by Mr. Whidborne in 1882, and also proving that certain Brachiopods are abundant in both the northern quarries.

The above are all the special references to Lummaton Hill that I have been able to find, and from them I think it would be inferred that there was little worth seeing on Lummaton Hill beyond a massive limestone composed chiefly of corals, but including some patches or beds of shelly limestone, the relations of which to the main mass were somewhat obscure. I propose to

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* *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 503.

† *Mem. Geol. Survey. Explanation of Sheet* 350, p. 65, (19c3).

show that at least three different limestones enter into the composition of the hill and that each of these presents features of special interest.

In the first place and before describing these limestones let me express my appreciation of the excellent work done by my friend Mr. Ussher. This part of South Devon is one of the most complicated and broken-up portions of the British Isles, and when Mr. Ussher commenced his labours the very succession of the rocks in it was quite uncertain, and it took many years of careful observation and mapping, and a survey of the whole Devonian area east and south of Dartmoor, before he could establish the actual succession of the great series of beds. With regard to the Middle Devonian, he was able to show that the limestone series is divisible into a lower stage (partly Eifelian, partly Givétian) and an upper stage which is supposed to be partly of Middle (Givétian) and partly of Upper Devonian age. He states that the lower beds are generally darker in colour and more distinctly bedded, and that crinoidal limestones are common in them; while the upper series consists mainly of massive limestones generally of a pale colour and without any distinct bedding.

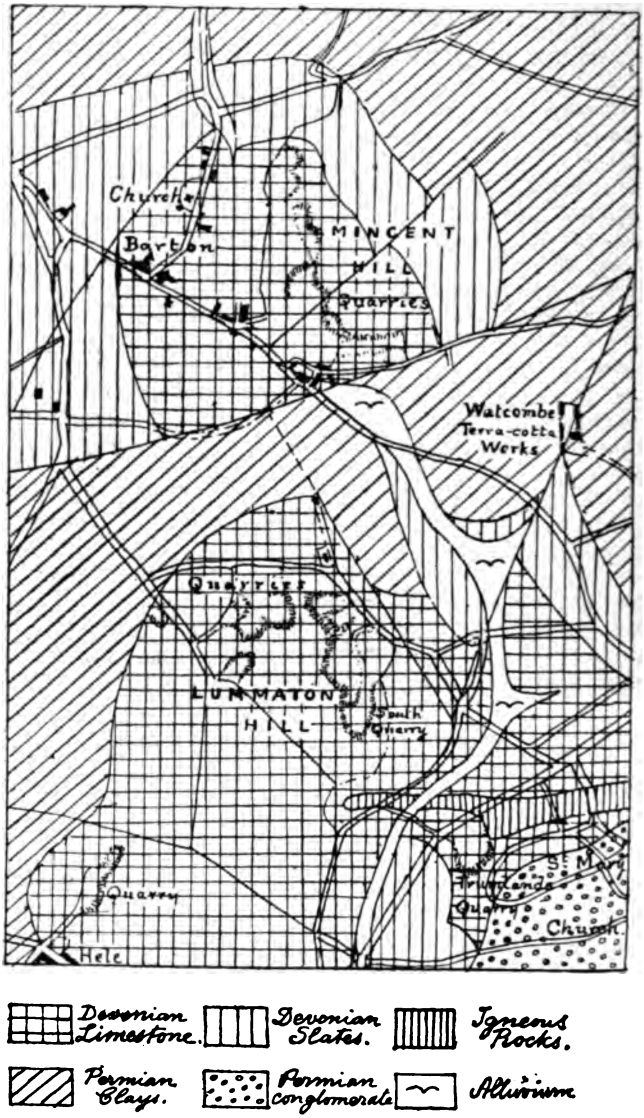
Thus Mr. Ussher's work, while greatly advancing our knowledge of this limestone series, leaves it without any well-defined middle portion. No one who knows the country round Torquay will be surprised at this, for the district is so flexured and faulted that the limestones form a number of small isolated patches, and it is very difficult to make out any sequence in them for more than a short distance, or to collect a sufficient number of fossils for palæontological comparison. Large portions indeed contain few fossils except Stromatoporoids and scattered corals.

Lummaton Hill is part of one of these isolated limestone masses, but one in which exposures are numerous, and it so happens that two of the quarries have been worked during this year (1905), thus exposing fresh faces of limestone to observation; while the southern quarry has remained unworked, and the structure of that portion of the limestone is beautifully shown on its partly weathered surfaces.

2. Evidence of Succession.

I will first briefly state my reasons for thinking that a definite and nearly continuous succession can be made out in this limestone-mass, and will afterwards describe the quarry-sections in detail.

The starting-point, or basis, of the stratigraphical evidence is Trumland's quarry on the Teignmouth Road, a little south-east of Lummaton Hill. This quarry is mentioned by Mr. Ussher as



GEOLOGICAL MAP OF THE LUMMATON AND BARTON DISTRICT.

(By permission of the Director of the Geological Survey and adapted from the 6-in. Geological Survey Map by W. A. E. Ussher, with some modifications.)

exposing limestone belonging to his lower division, dipping in a northerly direction at an angle of about 35 deg., and he obtained here specimens of *Heliolites porosus* and *Stromatopora hupschi.*

My notes on this section are as follow: The beds seen are crystalline bedded limestones, some layers more compact than others, but all obviously composed chiefly of crinoid fragments, and the prevalent colour of the rock is purple or purplish-grey. Stromatoporoid growths occur here and there, but sparsely, and corals are rare. The dip appears to be N.N.W. at 30 deg. or 35 deg. These limestones, as noted by Mr. Ussher, dip under grey and brown calcareous tuffs at the north end of the quarry.

Near the Palk Arms to the north-east Mr. Ussher found an out-crop of similar tuffs associated with shales which overlay even-bedded limestones, and he remarks: "It appears therefore that these limestones are lower than those in the Lummaton mass adjacent, and, if evidences of the superposition of shales and schalsteins upon them may be relied on, that there was here an interval during which local volcanicity and muddy sedimentation took place."

It occurred to me that if this view was correct some confirmation of it ought to be discoverable by a close scrutiny of the ground between Trumland's quarry and those on Lummaton Hill. Accordingly I examined the sides of the lane which skirts the eastern base of that hill, and nearly opposite Trumland's quarry and only 80 yards from the outcrop of the tuff I found an exposure of hard purple crinoidal limestone exactly like beds in the quarry. A little above this and in the field which forms the eastern slope of Lummaton Hill is a small overgrown excavation in and around which are scattered many lumps of dark grey and purple limestone and some fragments of *Stromatoporæ.* In one block I found the pygidium of a Trilobite, which has been examined by Dr. F. L. Kitchen and Dr. Ivor Thomas, who agree in referring it to the genus *Phacops,* but cannot determine the species, which is rather a large form. Pieces of similar limestone occur in the soil of the southern part of the field up to the edge of the grassland, just below the contour of 300 ft., and above this level light grey limestone crops out through the soil and appears also in a craggy face to the westward.

These facts prove the existence of grey and purple limestones on the eastern slope of the hill; they occur through a vertical height of about 70 ft. and a horizontal distance of about 250 ft. With a dip of 30 deg. this distance would bring in on the same level a thickness of 125 ft., so that there may be about 200 ft. of the lower bedded limestones on this slope. It is possible that the valley between this slope and Trumland's quarry is occupied by shales and tuffs, and that the limestones on the eastern side of the valley are entirely below those on the western, as Mr.

Ussher has surmised. On the other hand there may be a fault between the exposures, the limestones on the west being in that case a repetition of those on the east. For my present purpose it is sufficient to have shown that the lower limestones do enter into the structure of Lummaton Hill, and that they presumably dip to the N.W., so as to pass below the limestones of the well-known Lummaton quarries (see map, page 277).

If we ascend to the top of this eastern slope we look down into the first or most southern of the Lummaton quarries, and this is excavated entirely in a light-grey massive limestone, which is composed chiefly of Stromatoporoids, and in which no bedding is discernible. Brachiopods are seldom seen in this limestone.

We may reasonably suppose that the N.W. dip is still maintained, and this supposition is confirmed when we pass to the northern part of these eastern quarries, for west of a line which seems to run about S.S.W. to N.N.E. there is a gradual change from the Stromatoporoid limestone to a grey shelly limestone. There are faults here, and the rock in the upper part of the quarry face is largely dolomitised, so that it is not easy to make sure of any succession, but I shall describe what seem to be passage beds between these two limestone-facies. The shelly limestone yields many Brachiopods and other fossils.

In the more western quarries there are both shelly and crinoidal limestones, but even here no bedding is observable. In these quarries *Stringocephalus burtini* and *Rhynchonella cuboides* occur together, but at the north-west end certain corals are common which do not occur or are very rare in the eastern quarries.

From the evidence above given, therefore, I conclude that there is a definite succession from older to newer beds as one passes from the eastern to the western sides of Lummaton Hill; that the beds which crop out on the eastern slope of the hill belong to Mr. Ussher's lower division, but whether they are Givétian or Eifelian there is not sufficient evidence to decide. The beds in the quarries all belong to the Upper Limestone division of the same author, but there are certainly two different kinds or facies of limestone; the Stromatoporoid limestone only occurs in the south-eastern quarry and is therefore presumably older than the shelly limestone which has yielded the assemblage of fossils known as the Lummaton fauna.

3. Description of the Quarry-Sections.

There is no need to describe the relative positions of the quarries, for these can be seen by an inspection of the map. The southern part of the large eastern quarry has not been worked for 7 or 8 years, the central part has been largely quarried during 1905 for road metal, and the northern parts were quarried for several years up till 1904, both for road metal and building-stone. The quarry at the north-western corner of the hill had not been worked for many years, but was re-opened in 1905, some of the stone being burnt for lime and some used for road-material. There is another old quarry south of the last which has not been worked for many years; most of it is dolomitic limestone, but a patch of shelly limestone occurs in one corner. Finally, a small quarry has been opened in dolomitic limestone still farther to the west.

It will be convenient to begin at the southern end of the eastern quarries. The floor of this excavation is nearly level, and I found it to be 40 long paces across—*i.e.*, about 120 ft.—while the western face is about 40 ft. high, so that if the dip is to the north-west and its amount about 35 deg. the total thickness of limestone brought in here will be about 90 ft.

The point which strikes the observer who visits this quarry in its present state is that the rock-faces have been weathered to an extent which is just sufficient to bring out clearly the component organisms of the rock; these being very little obscured by any dark staining or by growth of lichen, as is often the case in old excavations. As a consequence it is easily seen that this limestone is largely composed of Stromatoporoid growths. These organisms occur as lumps or masses of very irregular shape, some being more or less round or oval, but others sending out protuberances or forming elongate growths; they also vary in size from a few inches across to large masses 3 or 4 ft. in length. The largest which I measured was 4 ft. high by 2¾ ft. broad. Many of them show the concentric layers of growth very plainly, the commonest form having the characters of *Actinostroma stellulatum*, especially those of the third variety described by Nicholson, which seems to have grown outward in a series of close-set cylindrical or dome-shaped protuberances; so that in section they present beautiful patterns in curved lines or bands of alternating whitish and pale grey tints. *Stromatopora concentrica* is also common.

In many parts of the exposed surface the area occupied by *Actinostroma* and other Stromatoporoids represents more than half the mass of the rock, so that it is truly a Stromatoporoid limestone. They are easily distinguishable from the rest of the rock by their lighter tint and compact, homogeneous texture, even when they do not exhibit wavy or concentric lamellæ. The limestone material which fills up the spaces between the Stromatoporoid growths consists of broken pieces of *Favosites* and other corals, with fragments of crinoids, but shells of Mollusca or Brachiopoda are rare. Small growths of *Heliolites* are found, but are generally pieces which are overgrown by

Stromatoporoids, and look as if they had been killed by the enveloping growth of the latter.

The light-grey limestone can be followed northward along the north-western face of the quarry above a lower excavation, and is seen to pass into a grey rock in which Stromatoporoids do not form so large a part of the mass, though still very numerous. We then reach a place where much stone has been quarried during this year (1905), and here we find a limestone in which broken corals and various organic fragments occupy more space than Stromatoporoids. The upper part of the cliff has been altered into a white crystalline limestone by dolomitisation, and it is broken by a fault which rises steeply to the W.N.W., and is filled by a breccia of angular limestone fragments embedded in a matrix of reddish dolomite.

Returning to the floor of the quarry and passing northward we find a grey shelly limestone composed of Brachiopod shells, crinoid fragments, broken corals and bryozoa, with some scattered Stromatoporoids. The same kind of limestone is exposed in the next excavation to the north, which has been worked down to a lower level and carried farther also to the west. Here I noticed pieces of *Favosites* (*Pachypora*) *cervicornis*, a small *Cyathophyllum*, and a specimen of *Emmonsia hemispherica*, but there are no large pieces of coral, nor anything like coral-growths. Shell fragments seem to be abundant, though perfect shells are not common. The rock is certainly not coral-reef rock, but is simply a limestone made up of the various kinds of organisms that are likely to have lived and died on a sea-floor beneath no great depth of water. The largest organisms are still Stromatoporoids, but these are of moderate size (from 6 to 10 ins. across) and are of the more compact kinds.

Passing to the most northern branch of the quarry, which has also been carried still farther to the west, I found that the present face shows a grey shelly limestone occurring in patches surrounded by pale yellow and whitish crystalline limestone, both being traversed by veins and patches of red crystalline rock. Suspecting that these highly crystalline portions were more or less dolomitic, I desired to have analyses made, and for the following I am indebted to the kindness of Mr. G. S. Blake, of the Imperial Institute:—

		Pale Rock.	Red Rock.
SOLUBLE IN HYDROCHLORIC ACID.	Lime	32.46	29.31
	Magnesia	19.25	17.37
	Carbon-dioxide (including water)	46.60	42.92
	Ferric oxide & Alumina	.59	1.65
INSOLUBLE.	Silica	.42	4.62
	Alumina	.48	3.70
		99.80	99.57

Mr. Blake observes that if the proportions of lime, magnesia and carbonic acid are recalculated from the above quantities the relative amounts are found to agree very closely thus :—

	Pale Rock.	Red Rock.
Lime	33.01	32.71
Magnesia	19.58	19.39
Carbonic dioxide	47.41	47.90
	100.00	100.00

Moreover the proportions of these ingredients in the pale rock are almost exactly those of pure dolomite, and the principal chemical difference between the two rocks is the quantity of silicate of alumina present in the red rock.

The patches of grey shelly limestone occur irregularly both in the lower and the upper part of the cliff, and their borders merge into the dolomite in such a way as to make it clear that the shelly limestone represents the original condition of the mass and that these patches are simply the unaltered portions of the rock.

It is from this grey shelly limestone that the well-known Lummaton fauna has been obtained, and it was from a weathered patch of grey rock at the top of this quarry that Mr. Whidborne obtained a large number of the specimens in his collection. He informs me, however, that this patch appeared to be a portion of a special bed which consisted chiefly of small and young shells, with very few of the larger species of Brachiopoda. Most of the patches of shelly limestone do not contain these small shells, but yield *Stringocephalus burtini*, *Rhynchonella cuboides*, *Spirifera curvata*, and other shells of similar size. Crinoids, or rather crinoid fragments, are very abundant in this limestone and are often the most obvious components; corals occur, but the only species that is common is *Pachypora cervicornis*. Stromatoporoids are also very common, but are seldom of large size.

No part of this limestone resembles coral-reef rock such as I have seen in the raised reefs of Barbados. Corals are not more abundant in it than are Stromatoporoids, and none of the corals which occur in the Torquay limestones have the aspect of modern reef-building corals; even the growths of *Smithia* and *Acervularia* are seldom more than 7 or 8 ins. across, and where corals are abundant they are generally limited to definite beds, and seem to be merely the remains of coral-fields or growths on the sea-floor.

No bedding can be distinguished in this limestone; it is massive, but traversed by joint planes which cross one another and break it into angular blocks. Movement has taken place along some of the master-joints, the faces of which show slickensides. The western face of this quarry intersects another fault which seems to run nearly parallel to the one previously mentioned, and like it is filled with fault-rock consisting of red dolomite, enclosing fragments of the white and yellowish dolomite.

Here and there are pockets or cavities filled with what looks like red sand, but this is merely decomposed and disintegrated dolomite, consisting entirely of broken rhombic crystals, without any admixture of quartz sand. Some of these pockets when cleared out are big enough for two men to stand up in.

The western face of the quarry last mentioned is only separated by a strip of ground about 50 ft. in width from another, which I shall call the north-western quarry. This has also been largely worked in 1905, and the limestone in its eastern part is the same as that just described. Parts of it are dolomitized, but the larger part is unaltered. Brachiopods are common, especially *Stringocephalus burtini*, *Spirifera curvata*, *Rhynchonella cuboides*, and *Atrypa reticulata*. A Stromatoporoid which I take to be *Actinostroma hebbornense*, forming compact dark grey masses, is also abundant, but I did not see any corals except the usual small pieces of Favosites (Pachypora).

The western part of the quarry exhibits limestone of more varied composition, though even here it is difficult to make out any definite beds. It seems rather to vary in a patchy way, some portions being full of *Pachypora cervicornis*, and others being largely composed of crinoid-fragments and Brachiopod-shells. Other parts are of finer grain and seem to consist of a fine matrix in which the small arm-ossicles of crinoids are abundant. In all parts Stromatoporoids are not uncommon, but they are not specially numerous.

Along the western side, however, certain corals come in which are either absent or rare to the eastward; these are *Smithia hennahi* and *S. pengellyi*, the former being the most abundant. This fact is interesting because these corals are characteristic of the limestone found in the Barton quarry about half a mile to the N.E. of this point.

South of the last quarry there is another old excavation in dolomitic limestone with a patch of unaltered but much weathered grey limestone at the top of the eastern corner. It is from this patch that many of his fossils, as Mr. Whidborne informs me, and especially the Trilobites, were obtained. This appears to be similar to the other fossiliferous patch and, like it, contains many small Brachiopods, such as *Centronella virgo*, *Magellania juvenis*, and *Merista plebeia*. It is possible that these patches are portions of lenticular beds or shell banks arranged by the action of currents, but I see no reason to regard them as "littoral deposits" or as "shell heaps" in any other sense than that above expressed.

If the dip in these northern quarries is at all steep there must be a considerable thickness of these shelly limestones. Along a line measured from S.S.E. to N.N.W. there is a space of about

400 ft. occupied by them, and if the dip is only 30 deg. this will bring in a thickness of 200 ft., provided that there is no duplication by faults.

Summary and Conclusions.

This account of the limestones of Lummaton Hill has been written because no adequate description of them had been published, and because I had found that three different types or kinds of limestone entered into the structure of the hill and occurred in a definite order. Whether they form a complete succession or one broken by faults can only be determined by comparison with other localities.

I claim, however, to have shown that limestones belonging to the lower division of the series form the basal part of the eastern slope of the hill. These beds presumably dip to the N.W. below the limestones exposed in the quarries, for the line of junction appears to strike in a N.E. direction, but I cannot say that this is not a line of fault.

The next point of importance is the recognition of a limestone which is mainly composed of Stromatoporoids. Nicholson in the Introduction to his monograph on these fossils* remarked that "whole beds of Silurian and Devonian limestone being often essentially made up of the remains of these organisms," but he does not seem to have been aware that any of our own British limestones were so composed. On the continent, and especially in Belgium, "Stromatoporoid limestones" have long been known to occur both in the Givétian (Middle Devonian) and in the Frasnian (Upper Devonian) limestones. It is therefore high time that such limestone was recognised in this country as a definite limestone facies and as a component of our Devonian System, for it has a character of its own which is quite as striking as that of coral-limestone or crinoid-limestone. Moreover, its recognition is likely to be useful in establishing a succession at other places near Torquay, for similar limestone occurs in the cliffs south of Babbacombe, and Mr. Ussher mentions "limestones rich in Stromatopora" near Goodrington,† but these latter I have not yet seen.

I think it is largely owing to the massiveness imparted by the large Stromatoporoids that the absence of bedding is due, for this limestone was evidently formed by the filling-up of the spaces between the Stromatoporoid growths, so that anything like stratification was almost impossible.

With regard to the third type of limestone, which has been described as "coralline," and even as "part of a coral-reef," I have shown that it does not contain any corals which by their

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* *British Stromatoporoids, Pal. Soc.*, Part 1. p. 29. (1885).

† *The Geology of Torquay, Mem. Geol. Surv.* p. 74. (1903).

size and manner of growth bear any resemblance to modern reef-building corals. Even some of the pieces of *Smithia* which occur, both in the Lummaton and Barton quarries, are obviously broken fragments embedded in the limestone, and did not grow where they are now found. The remains of corals do not form so large a part of the rock-mass as they do in modern reefs, or as Stromatoporoids do in the adjacent limestone. As a matter of fact the rock in question is not a coralline limestone but a shelly limestone, consisting mainly of the broken remains of Crinoids and Brachiopods.

We know from the experience of the naturalists on board the "Challenger" and the U.S. steamship "Blake," that Crinoids often grow in large colonies which cover wide spaces on the sea-floor. Parts of this shelly limestone suggest that they were formed by such colonies or fields of Crinoids, among which also grow the branching *Pachypora cervicornis*, while attached to the bases of both were the various Brachiopods and Bryozoa which are so common in this limestone. All these creatures may have lived and died together on the floor of a sea which was neither shallow nor very deep, but suited to the quiet growth of the Crinoids and of the delicate Bryozoa.

Another point of interest in the Lummaton quarries is the transformation of large parts of this shelly limestone into dolomite, for all the local evidence points to the conclusion that this alteration of the limestone was effected by the waters in which the Permian Beds were deposited.

The dolomite is only found in the western part of the hill, on which side the limestone passes directly under the Permian Beds; it does not occur on the eastern side, which slopes to the valley and has been exposed in comparatively recent times. Again, the red dolomite which fills the fissures and faults in the limestone is evidently coloured by a red clay which seems to have been carried in and disseminated along with the water which effected the dolomititation of the rock. Now the lowest Permian deposit in the neighbourhood is the fine red clay of Watcombe, which has long been worked for making terra-cotta ware. It is this clay which overlies the limestone on the west, and it is therefore a reasonable inference that the alteration of the limestone was accomplished either just before or during the time when this red clay was being deposited on the top of it. Very probably the light-coloured dolomite was formed before the red clay was brought into the area, and the red rock was of subsequent formation, for it certainly penetrates the former as if this was the case.

THE FELSITIC AGGLOMERATE OF THE CHARNWOOD FOREST.

By F. W. BENNETT, M.D., B.Sc.

(*Read Friday, May 4th, 1906.*)

HITHERTO the Felsitic Agglomerate has been regarded as a well marked bed lying between the Blackbrook rocks below, and the Beacon Series above. The rock is an ash containing abundant scattered masses of pinkish felsitic material. All rocks below this band have been regarded as Blackbrook rocks. During the last winter, aided by Dr. Stracey, I have examined in detail the rocks of the north-east part of the Forest. We have succeeded in showing that there are really a series of beds between the Blackbrook and Beacon Series, which, when occurring, always occupy a definite order. Omitting the less important bands, we must recognise in future three bands as forming the Felsitic Agglomerate Series. There is a somewhat coarse grit below, followed by a white grit, and the pink grit—*i.e.*, the rock hitherto regarded as the Felsitic Agglomerate band—forms the highest member of the Series.

These features are very constant in places far apart. At Collier's Hill, on the west side of the Forest, the lower grit is very well marked. The white grit occurs, but is not well defined. The pink grit almost exactly resembles that on the east side in the Nanpantan area.

Running through the centre of the Beacon Series, near Nanpantan, is a peculiar grit-band known as the Buck Hill Grit. It has been mentioned by Prof. Bonney and by Prof. Watts as a special grit-band in the Beacon Series. The specimens which I have brought prove without any possible question that this grit-band represents the coarse grit of the Felsitic Agglomerate Series. The sub-divisions of this coarse grit are all distinctly found and, underlying it, typical Blackbrook rock occurs in places. We have lately been able to find the white grit above the coarse grit in two or three spots, and in one small exposure we have found the pink grit.

As this band lies in the middle of the Beacon Series it is clear that the surface exposure of the Beacon rocks is largely increased by reduplication of the beds due to faulting.

From this point we have traced a grit-band in four places to Beacon Hill. The grit closely resembles the lower grit of the Felsitic Agglomerate, but it seems to have Beacon rock both above and below it. It probably represents a line of faulting by which some of the Felsitic Agglomerate Series has been exposed, but it is difficult to account for the exact conditions found.

Fuller details will be found in the "Transactions of the Leicester Literary and Philosophical Society."

REFERENCES.

HILL, Rev. E., and Prof. T. G. BONNEY.—*Quart. Journ. Geol. Soc.*, vol. xxxvi.

WATTS, Prof. W. W.—*Memoirs of the Geological Survey* (141).

ORDINARY MEETING.

FRIDAY, FEBRUARY 2ND, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

The following were elected members of the Association : Richard Bangay, J. Kershaw, Douglas Leighton. Harry Muller, F. G. Penman, Robert Heron Rastall, B.A., F.G.S.

There being no further business the meeting then terminated.

ORDINARY MEETING.

FRIDAY, MARCH 2ND, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

The following were elected members of the Association: Maurice M. Allerge, Charles P. Chatwin, Thomas Kelsey Francis Page, Alfred Sutton, A.R.S.M., Thomas Henry Withers.

The following papers were then read: "Note on an Ostracodal Limestone from Durlston Bay, Dorset," by Frederick Chapman, A.L.S., F.R.M.S.; "Remarks on the Upper Chalk of Surrey," by A. J. Jukes-Browne, B.A., F.G.S.; "The Devonian Limestones of Lummaton Hill, near Torquay," by A. J. Jukes-Browne, B.A., F.G.S.

ORDINARY MEETING.

FRIDAY, APRIL 6TH, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

The following were elected members of the Association: Miss Kathleen M. Crosse, Robert Gilling, Albert E. Morran, Miss S. Sheffield.

The following lecture was then delivered: "The Pressure

Chipping of Flint and the Question of Eolithic Man," by S. Hazzledine Warren; illustrated by specimens and lantern slides, and by a demonstration of the process of pressure chipping by means of a hand press.

Messrs. Frank Lasham and Martin A. C. Hinton also exhibited Specimens of Eoliths.

ORDINARY MEETING.

FRIDAY, MAY 4TH, 1906.

R. S. HERRIES, M.A., F.G.S., President, in the Chair.

The following were elected members of the Association: Edward J. Baily, Vernon P. Kitchin, B.A., Howard Lecky Sikes.

The following lecture was delivered: "The Erosion of the Batoka Gorge of the Zambesi," by G. W. Lamplugh, F.R.S., F.G.S.; illustrated by lantern slides.

Dr. T. W. Bennett also read a note "On the Felsitic Agglomerate of Charnwood Forest," and exhibited specimens in illustration.

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY).

MARCH 10TH, 1906.

Director: DR. A. SMITH WOODWARD, F.R.S.

(*Report by* THE DIRECTOR.)

THE party of about fifty assembled in the Central Hall and were met by Dr. Woodward, who accompanied them to the Galleries of Fossil Reptiles and gave a demonstration. He remarked on the historic interest of the collection, which comprises many of the original fossils to which our first knowledge of extinct reptiles is due. He also alluded to several recent acquisitions of special importance.

Among the Mosasauria, or marine lizards of the Cretaceous period, there is a piece of jaw of the typical *Mosasaurus* from Maastricht, obtained at the same time as the original specimen now in Paris, and presented to the British Museum by Dr. Peter Camper, through Sir Joseph Banks, in 1784. There are also most of the fragments of Mosasauria hitherto discovered in the English Chalk. These are now illustrated by fine portions of skeletons of allied animals from the Chalk of Kansas, U.S.A., which clearly show that the Mosasaurians were essentially large lizards with paddles, completely adapted for life in the sea.

Among Pterosauria or Ornithosauria the Museum possesses some of the earliest skeletons described from the Lower Lias of Lyme Regis and the Lithographic Stone of Bavaria, besides the fragmentary hollow bones from the English Wealden and Chalk, which were originally mistaken by Mantell and Owen for the bones of birds. The acquisition of more satisfactory specimens has now culminated in considerable portions of the skeleton of the gigantic Pterodactyls of the Cretaceous period, discovered in the Chalk of Kansas. An actual pair of wings of the toothless *Pteranodon*, mounted on a picture, measures 18 ft. 2 in. in span. A model of a slightly smaller skeleton of the same genus, recently made by Dr. G. F. Eaton, and presented to the Museum by Yale University, shows in a striking manner the relatively small size of the body and the weakness of the hind limbs in these animals. The immense wings were probably raised by muscles attached to the extended crest at the back of the head. The thinness of the hollow wing-bones is best shown by uncrushed specimens from the English Chalk, all those from the Kansas Chalk being flattened by pressure in the rock.

The original gigantic but very fragmentary paddle from the

Lower Lias of Lyme Regis, to which the name *Ichthyosaurus* was originally given by König in 1818, is a specimen of historic interest. Of still greater interest are the fine original specimens of *Ichthyosaurus* in the Hawkins Collection. To these have lately been added two remarkable skeletons supposed to prove that the Ichthyosauria were viviparous. One skeleton, from the Lower Lias of Somersetshire, contains a single small embryo, and was described by its discoverer, Dr. Channing Pearce, in 1846, besides receiving notice in Mantell's works. The other skeleton, from the other Upper Lias of Würtemberg, exhibits within the ribs remains of six embryos of considerable size.

Among skeletons of Plesiosauria acquired during recent years the most striking is that of *Cryptoclidus*, completely disinterred from the Oxford Clay of Peterborough by Mr. Alfred N. Leeds. Being mounted on a frame like a modern skeleton, all parts can be readily examined. The great expansion of the bones supporting the fore and hind paddles, and the covering of the intervening space with rows of abdominal ribs, are well shown; and the curious backward displacement of the iliac bones, as if by the thrust of the hind paddles, is conspicuous. A fossilised stomach of one of these Plesiosaurs from the Oxford Clay contains a collection of stones which must have served to pulverise the food. Such stones have now been found with the skeletons of many Plesiosaurs of the Cretaceous period, but it does not seem to be generally known that they were discovered and rightly interpreted so long ago as 1865* by Mr. Thomas Codrington, F.C.S., who has lately presented to the Museum his original specimen from the Upper Greensand of Savernake.

Most of the earliest discoveries of Dinosauria are represented by specimens in the Museum, the whole of the Mantell, Beckles, Fox, and other collections having been acquired. Recent additions are also of special importance.

The armoured Dinosaur, *Polacanthus Foxi*, from the Wealden of the Isle of Wight, has been mounted under the direction of Baron Franz Nopcsa, and now displays its principal characters very clearly. There seem to have been two rows of triangular spines along the back, diminishing in size from the shoulder backwards; there are also two rows of similar but smaller triangular spines along the tail. Between them, over the hip-region, is placed the continuous shield consisting of low bosses of bone fused together. The restoration of *Polacanthus* suggests that the late Prof. Marsh may have been mistaken in his arrangement of the bony plates of the allied genus, *Stegosaurus*, now familiar in popular books. It may be that these plates should be represented as diminishing, not increasing, in size above the hips.

The plaster cast of the skeleton of *Diplodocus Carnegii*, from

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* *Wilts Archæol. and Nat. Hist. Mag.*, vol. ix, p. 170.

the Upper Jurassic of Wyoming, presented by Mr. Andrew Carnegie in 1905, is the first attempt to give a complete view of one of the gigantic Sauropodous Dinosaurs. This specimen is not a restoration in the ordinary sense, but consists almost entirely of plaster casts made direct from actual bones. The vertebral column from the second cervical to the twelfth caudal is an exact copy of specimen No. 84 in the Carnegie Museum, Pittsburg, without any restoration, and the scapulæ, pelvis, and femora are taken from the same individual. Caudal vertebræ, Nos. 13 to 35, are from a second specimen in the Carnegie Museum (No. 94), which also furnished the tibiæ, fibulæ, and hind feet. The whip-like end of the tail (caudal vertebræ, Nos. 36 to 73) is an exact copy of a third specimen in the Carnegie Museum (No. 307), which also provided material for the slight restoration of the back of the skull. Nearly the whole of the skull is taken from Prof. Marsh's unique specimen in the National Museum, Washington; while the atlas vertebra, some chevron bones, and the fore feet are copies of specimens in the American Museum of Natural History, New York. The complete skeleton measures 84 ft. in length, and stands 11 ft. 6 in. high at the hind limbs. The terminal lash of the tail is a new discovery, and is probably to be explained as the animal's weapon of offence and defence. The remains of the actual tail and fore and hind limbs of *Cetiosaurus Leedsi* discovered by Mr. Alfred N. Leeds in the Oxford Clay of Peterborough, are interesting for comparison. They represent an animal about 60 ft. in length, with a similar terminal lash to the tail. All the vertebræ are remarkably light, but those of *Diplodocus* consist of plates and bars of dense bone arranged at different angles to give the greatest strength, while the vertebræ of *Cetiosaurus* are constructed of loose and spongy bone, without many large cavities and buttresses. A mounted hind limb of *Cetiosaurus oxoniensis* is as large as that of the American *Brontosaurus excelsus* placed by its side, but the knee-joint in the former is much lower than in the latter, which has a relatively longer shin.

VISIT TO THE ESSEX MUSEUM OF NATURAL HISTORY, ROMFORD ROAD, STRATFORD, ESSEX.

MARCH 17TH, 1906.

Director: W. COLE, F.L.S., F.E.S.

Excursion Secretary: THOS. W. READER, F.G.S.

(*Report by* WM. COLE AND T. W. READER.)

THE party, numbering twenty-eight, was welcomed by Mr. Cole in the Library, where he gave a few words of explanation of the purpose and methods of the Museum. It is the outgrowth of the Essex Field Club's Museum, which was founded with the intention of gathering a collection of specimens to illustrate the natural history, geology, and prehistoric archæology of the county of Essex; but it would be obvious to the visitors that the pretty building so handsomely fitted up with cases and cabinets would be beyond the ability of a local society to provide. The Museum, as it at present exists, is the result of the enlightened policy of the borough of West Ham, aided by a generous donation of £4,000 from Mr. Passmore Edwards and by subscriptions from the members of the club. The upkeep of the Museum is controlled under an agreement included in the West Ham Corporation Act, 1898, between the Corporation and the Essex Field Club, whereby the scientific management and the appointment of the Curator rests with the Club, while the care of the building as a public exhibition is in the hands of the Corporation.*

The Director pointed out that the objects of the Museum were three: (1) Educational; (2) the conservation of authentic sets of local (Essex) specimens; and (3) the encouragement of local observation and research. The possibility of fulfilling these three purposes was considered in a paper read at the South East Union of Natural History Societies in 1898, and the methods there indicated are being carried out in the Museum. The specimens publicly exhibited in the open cases are largely of an educational character, the longer sets of Essex specimens being placed in cabinets either open to the ordinary visitor or to be inspected on application to the Curator. The Educational specimens are of necessity restricted in number, and attempts are being made to illustrate principles rather than to tire the visitor by showing a multitude of objects.

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* The "idea" of the Museum works well practically, and this probably unique agreement should be studied by those interested in the establishment of local museums. Full particulars may be obtained from the E.F.C. Museum Handbook No. 3, and the Year Book E.F.C. for 1905.

The attention of the members was particularly directed to three or four collections which indicated the methods which the Curator is endeavouring to pursue. In a small room a series of specimens illustrating the principles of Protective Resemblance, Mimicry, etc., amongst insects were shown.

The collection of Mollusca was alluded to as an example of the plan to be eventually carried out in all the groups of the Invertebrata. First a small typical series of shells from all parts of the world is shown to familiarise the visitor with the group and to give an idea of classification; then a series to demonstrate the salient points of the external and internal anatomy of the Mollusca; thirdly, a set of the Essex species in cabinets, and fourthly, a case containing a series of the Cephalopoda arranged to show their geological history, and survival of the group to the present day.

Other special series shown were the "History of the Horse: a Lesson in Evolution," and a case containing specimens indicating the form, structure, and development of the earliest allies of the vertebrata.

Attention was also called to a very beautiful series of British Hawks, illustrating the old Essex sport of Falconry, which had been prepared and presented to the Museum by Mr. J. E. Harting, F.L.S.

In the Archæological section of the Museum Mr. Cole called attention to the curious "Red Hills" so frequently found in the estuarine marshes of Essex, which seemed to be remains of ancient pottery works, and to the "Dene-holes" at Grays, which had occupied the Club's attention for some years. Although the problem of these pits could not be considered as finally solved, Mr. Cole said that in the opinion of Mr. T. V. Holmes and himself the probabilities of their being store pits for food and possibly for shelter in troublous times were very great. The remains from the Pile dwelling found by the Rev. J. W. Kenworthy at Skitt's Hill, near Braintree, and a collection of pottery, etc., from Norsey Wood presented by Dr. A. E. Salter, F.G.S., also formed interesting matters of discussion.

Ascending the staircase, the party were then conducted by Mr. Reader over the Geological section. One end of the gallery is devoted to the collection of Crag fossils made and presented by Mr. W. H. Dalton, F.G.S., while at the opposite side are the Pleistocene remains from Ilford and the Lea Valley, the radial cases being devoted to the general series of fossils chiefly from the collections presented by Mr. Carvalho and Dr. Horace Brown, F.R.S., etc. The Rock collection, arranged by Mr. Thos. W. Reader, was then explained, and received considerable attention, as so many of the specimens there shown were collected by him to illustrate the various points of interest during past excursions of the Geologists' Association. The series commences with the question, "What is a rock?" the specimens shown being those found in the streets and ground round the Museum, such as the paving-stones and setts (hard) and sand and clay (soft). Then their use by primitive man, ancient and modern, as Palæoliths, which he made use of for various everyday purposes; flint and pyrites for obtaining fire, and modern stone adzes, still in use by the Islanders of the South Seas. Following this are a number of examples of rocks used by us for building, decoration, and various manufacturing and commercial purposes, followed by their formation in various ways by the agency of heat, water, animals, and plants. The next case is devoted to the composition of rocks, showing that they are built up of a number of minerals, and specimens of the chief rock-forming minerals were there exhibited. A number of interesting forms of structure, fracture, coherence, and colour are then shown. Next came a series illustrating the various changes undergone since deposition by breaking up processes, such as the action of ice, moving water, wind, and disengaged gases, earth movements, chemical action, heat, and the agency of organisms. After this introduction the general collection follows, in which are found examples of all the classes into which rocks are divided, the last case being devoted to a series of the various kinds of "road-metal" used in the borough of West Ham.

On the walls of the gallery are arranged a fine series of Essex prints kindly lent by Mr. J. Avery.

A vote of thanks was proposed by the President (Mr. Herries, M.A.), and the party then returned to town.

VISIT TO THE MUSEUM OF MR. G. E. DIBLEY AT LOWER SYDENHAM.

SATURDAY, MARCH 24TH, 1906.

(*Report by* C. DAVIES SHERBORN.)

MR. DIBLEY'S collection, besides containing a general series, is notably rich in fossils from the Chalk, both Grey and White, although despoiled of many of its richest treasures, which have gone to fill gaps in the British Museum (Natural History).

Despite the weather thirty-two persons visited Sydenham, and were hospitably received by Mrs. Dibley.

So much interest has of late years been spent upon the Chalk, and so much progress in our knowledge of that deposit made, that the exhibition of so fine a series of zoned specimens was most instructive and interesting. They are nearly all

Kentish and formed the basis of Mr. Dibley's paper on the Kentish Chalk.

The most important remains are undoubtedly those of the vertebrata, and certainly in no other collection existing could one have seen thirty-one associated sets of *Ptychodus* teeth. This exhibition was even better formerly, for four other sets once belonging to Mr. Dibley are now in the National Collection. Other fish remains bear marks showing that they have been figured by Dr. Smith Woodward. A gem among the vertebrates was an extremely fine and complete lower jaw of the lizard *Leiodon.*

The invertebrata are numerous, all arranged zonally, and sometimes bearing notes that they are figured types, notably some *Pectens* used by Mr. Henry Woods for his Palæontographical Monograph. The series of *Ammonites* obtained by Mr. Dibley are nearly all at the British Museum, being too bulky for his own accommodation. They are numerous, present endless new features, and in the able hands of Mr. G. C. Crick will, we have no doubt, largely increase our present knowledge of Chalk *Ammonites* and their distribution.

EXCURSION TO WHETSTONE AND NORTH FINCHLEY.

SATURDAY, MARCH 31st, 1906.

Director: GRIFFITH HUMPHREYS.

Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTOR).

HAVING assembled at Whetstone Station, a party of 30 members and friends proceeded to the Oakleigh Park gravel pit, where the Boulder Clay was seen overlying the Mid-Glacial Gravels of S. V. Wood, Jnr.. This pit was previously visited by the Association in 1894 under the leadership of Dr. Hicks of Hendon.

A move was then made to the Woodside Park Lane pits, where excellent exposures of Upper and Middle Glacial Drift were inspected. Many erratics and some of the characteristic derived fossils were found by the members, and the Director showed some Gryphææ, Belemnites and a vertebra of the Ichthyosaurus, together with transported blocks of Carboniferous

Limestone and Sandstone, Millstone Grit, Jurassic Limestone, Glaciated Chalk, Red Chalk of the Hunstanton district, Chert, laminated Quartzite, Iron ore, and some igneous rocks, which he had recently obtained from these beds. He then drew attention to the colour of the Boulder Clay, which loses its familiar blue shade on exposure and turns brown, when it might easily be mistaken for London Clay, until the characteristic boulders are forthcoming, or the subjacent gravel is reached. This gravel consists mainly of subangular flints, some quartzite pebbles, and other erratics, together with derived fossils such as occur in the Boulder Clay. It is interstratified with sand and loam, but contains no shell fragments such as occur in the Glacial sands on the coast of East Anglia. The London Clay lies immediately below the gravels and sands.

Mr. Humphreys then briefly recapitulated the views expressed by directors of previous excursions as to the origin of the Finchley deposits, together with the explanations usually advanced to account for the Glacial Drift, as follows:—

On the occasion of the Association's visit in 1873, Mr. Henry Walker, whose researches at Finchley at that time made "any attempt at competition useless," gave it as his opinion that "the accumulations at this spot belong to the period of the submergence of England beneath the Glacial Sea, and are not the immediate products of land ice." In 1887 Messrs. J. C. Goodchild and H. B. Woodward, speaking at Summer's Lane, strongly advocated land ice as the transporting agent. Dr. Hicks, whose famous researches at Hendon are widely known, speaking in 1894 of the Oakleigh Park Beds, "believed that the lower deposits had been accumulated in a fresh water lake during an early part of the Glacial Period." From this we learn that whilst the consensus of opinion as to the origin of the Boulder Clay points to ice as a solution of the problem the form of ice is a matter of dispute, and we have to choose between (1) floating icebergs dropping their cargo of erratics, and (2) land ice sheets causing a bottom-moraine by the grinding action of the thick moving mass. Other theories, such as coast ice acting on a slowly sinking area, and a great flood (by Sir Henry Howarth) have also been put forward. The manner in which the Glacial sands and gravels were deposited is generally explained in one of two ways, either during a great submergence which occurred in a period of amelioration of the Glacial climate, the floating icebergs transporting the boulders, or by ice sheets tearing up the sea floors which they traversed, the gravel being rearranged in places by Glacial rivers or lakes after its deposition. Mr. H. B. Woodward summarises these views when he says that "the Boulder Clay is the more direct product of the ice agents, the sands and gravels as a rule being due to streams and floods arising from the melting of the ice."

The Director then invited a discussion, in response to which Dr. A. E. Salter stated that the theories already put forward to explain the origin of these puzzling deposits had failed to satisfy him. Taking the underlying gravels first, he noticed that in addition to local material they contained a fair proportion of Lower Greensand Chert, which was derived either directly from the Wealden area or indirectly through older gravels, which existed to the north at about 100 ft. higher level. A small amount of Triassic débris was present, but at the Oakleigh Park pit nothing derived from the Jurassic system was seen. At lower levels Jurassic material was plentiful. As far then as the gravels are concerned, we appear to be dealing with a portion of a "Drift series" similar to that found all along the northern side of the Lower Thames Basin. In this case the gravels point to an old line of drainage, which was in existence before the present Thames Valley was formed.

There is good reasôn for believing that earth movements of an extended character considerably modified the synclinal trough of the Lower Thames Basin after the gravels with Triassic and local débris only had been laid down and before Jurassic material invaded the Lower Thames Basin.

Turning to the clay he noticed at the Oakleigh Park section, the highest seen, that it contained but little chalk, and the united efforts of the party failed to find any Jurassic débris. At the next section many scratched chalk pebbles were found and a few specimens of Jurassic rocks and fossils. At lower levels they are more common. On the Chiltern Hills, especially near Great Offley, the same chalk pebbles, etc., can be seen at 500 ft. O.D.

The Finchley Boulder Clay seems to consist of London Clay from the immediate neighbourhood, containing rocks derived from higher deposits to the north-west.

These latter were deposited in their present position by streams draining the vast area of chalk, etc., in Central England, which has been denuded away.

For these reasons he was inclined to regard the Drift Clay at this spot as having been the result of the alteration of the drainage of this part of the country by earth movements, and perhaps more intense fluviatile conditions, in consequence of which some of the old valleys had had their gravels smothered up by land slides or mud-glaciers.

In the Woodside Park pit there was evidence of rude stratification in the Clay, especially near its base.

To this Mr. Whitaker objected that the hard chalk pebbles were not from the Chilterns, as no bed of hard chalk cropped out there. Dr. Salter replied that in drifts on the edge of the Chiltern escarpment at 500 ft. O.D., near Great Offley, etc., the same chalk pebbles (scratched) could be obtained and were derived, according to him, from old chalk beds of the Midlands, now denuded away. The Red Chalk might have come in a similar manner, and not necessarily from Hunstanton.

The Director then led the way to the disused brickfield at Summer's Lane, where a seam of Boulder Clay was seen to apparently underlie the Glacial sands, the cutting not being sufficiently deep to show more sand below the clay. That this is actually the case has been fully demonstrated on a previous visit to Summer's Lane in 1887 (*vide Proc. Geol. Assoc.*, vol. x, p. 145), when Mr. H. B. Woodward called particular attention to these sheets of Boulder Clay interstratified with the Mid-Glacial gravels and sands.

A cordial vote of thanks was then proposed by the President, Mr. R. S. Herries, to which the Director responded.

On leaving Summer's Lane brickfield the party proceeded by electric tramcars to Highgate, where, after partaking of tea at the Gatehouse Hotel, Mr. G. Potter escorted the members to the Literary and Scientific Institution, where they were shown a number of fossils from the drift of Muswell Hill and Finchley, portions of the collection presented to the Institution by the late Mr. N. T. Wetherell. The most notable specimen was an Ammonite about a foot in diameter enclosed in a septarium (? Oxford Clay), portions of a much larger example, and other typical fossils of the district. Mr. Potter also exhibited from his own collection Belemnites, Gryphææ, Encrinites, Wood, Serpulæ, etc., obtained about half a century since from a brickfield opposite the White Lion, Finchley.

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New Ordnance Survey, Sheet 256.
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1866. Unrecorded.
1872. HICKS, H.—*Proc. Geol. Assoc.*, vol. iii, p. 115.
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1887. GOODCHILD, J. G., and WOODWARD, H. B.—*Ibid.*, vol. x, p. 145.
1894. HICKS, H.—*Proc. Geol. Assoc.*, vol. xiii, p. 367.

EXCURSION TO INGATESTONE AND BEGGAR HILL.

SATURDAY, APRIL 7TH, 1906.

Director: A. E. SALTER, D.Sc., F.G S.

Excursion Secretary: A. H. WILLIAMS.

(*Report by* THE DIRECTOR.)

MEMBERS left Liverpool Street Station at 1.55 p.m., and arrived at Ingatestone at 2.49 p.m., the party now numbering fifteen. The path leading through Stonefield to the Church was taken, and in the churchyard a large sarsen, which formerly formed part of the foundation of the Church, was examined.

The Director pointed out that the name Ing-ate-stone meant the meadow by the stone, and it was thought that a Roman milestone formerly existed here. Many interesting monuments to members of the Petre and Disney families were seen inside the Church. Nearly opposite the Anchor Inn, in the main road, were two large sarsens, one on each side of the entrance to Fryerning Lane, up which the party proceeded to the site of the bore-hole for the new Waterworks, where they were received by J. Dewhirst, Esq., A.M.I.Mech.E., who exhibited plans of the boring, which went down 800 ft., and the shaft 350 ft. Samples of the strata from various depths were exhibited, and members were able to examine the material obtained from below in the adjoining field. Mr. Whitaker, who was present, has very kindly allowed the following notes concerning this boring to be published here:

INGATESTONE WATERWORKS. TRIAL-BORING FOR THE CHELMSFORD RURAL DISTRICT COUNCIL, 1902.

Communicated by Mr. JAMES DEWHIRST, Engineer. (Remarks in these brackets from an account sent by Messrs. LE GRAND and SUTCLIFF, who made the boring). 255 (277) ft. above Ordnance Datum. Highest water-level [? from the Chalk] about 30 ft. above O.D. Lowest nearly 70 ft. below O.D. (Messrs. Le Grand say 200 ft. down). Boring decreases from 18 in. diameter to 6 in.

		Thickness. Feet.	Depth. Feet.
GRAVEL AND SAND		2	2
[LONDON CLAY.]	Sandy loam	4½	6½
	Blue clay	¾	7¼
	Sandy loam	12¾	20
	Blue sandy clay	7	27
	Blue clay and claystones (septaria)	31 (33)	58 (60)
	Blue clay, small stones, etc. (with water)	32 (22)	90 (82)
	Blue clay	418 (434)	508
	Blue clay and shells	8	516
	Sandy clay (blue. Pebbles at base)	16	532

		Thickness. Feet.	Depth. Feet
[?OLDHAVEN BEDS AND READING BEDS.]	Hard sand and pebbles	2	534
	Hard sand	23½	557½
	Sand and shells	7½	565
	Clay and shells	3	568
	Undescribed	1	569
	Stone	½	569½
	Sand peat [lignite] and clay ...	8½	578
	Sand (green)	9	587
	Green sand and brown clay ...	10	597
[? THANET BEDS.]	Greenish sand and small shells [carried down ?]	49 (50½)	646 (647½)
	Flints	½	646½
[UPPER CHALK.]	Chalk and flints	76	722½
	Rubble chalk	7	729½
	Chalk, with a bed of flints at 765 to 766 ft.	70½	800

The great interest of this section is that it shows a much greater thickness of London Clay than has been proved before, and even a greater total thickness than has ever been estimated. This is the more notable as the very topmost beds of that formation are here absent. On the other hand, the Lower London Tertiaries, with a total thickness of 114½ ft., are thinner than one would have expected here. Even if the last two beds classed with the London Clay be removed into this series, still the former will be of much greater thickness than before known.—W. W.

A hearty vote of thanks to Mr. Dewhirst was called for by the President, R. S. Herries, Esq., V.P.G.S., to which Mr. Dewhirst suitably responded.

The road to Fryerning was then resumed, and a few road sections in gravel were pointed out. The constituents appeared to be of local origin only.

On reaching the cross roads the Director pointed out the valley of the Wid, which ran *northward*, thus differing from all the other streams of any considerable size in Essex.

The road to Beggar Hill was then taken, and a large gravel pit on the edge of College Wood visited. Extensive old workings showed that gravel had been dug for many years.

The Director referred to the work of the late Searles V. Wood, Jun., who had devoted a great deal of attention to this kind of deposit, and had placed in the library of the Geological Society a MS. record of his observations, etc., with regard to them. He then stated that in the interpretation of superficial deposits such as that now before them three important factors demanded consideration :—

(*a*) Denudation in its various forms and effects, *e.g.*, general, fluviatile, solution of soluble rocks, etc. Many superficial deposits are simply " relics of denudation."

(*b*) Earth movements, by which lines of drainage may be disturbed and new ones produced. As a result also of (*a*), especially in areas like that visited this afternoon, soil creep, slipping and formation of mud streams may be produced.

(*c*) Climatic changes. At the time of the deposition of a gravel these may be of greater or less intensity than at the present day. The size of the blocks embedded in the gravel gives some evidence for comparison.

The effect produced by (*c*) may be roughly gauged by elimination of all the phenomena which can reasonably be explained by (*a*) and (*b*), and by considering what still requires explanation.

The deposit before them was rather over 300 ft. O.D., and being situated on the top of a hill and on the water-parting between the Wid and the Roding, showed that a vast amount of denudation had taken place since it was deposited.

It consisted of gravel about 15 ft. thick, which contained sandy patches and thin, irregular clayey layers, and was evidently laid down by a stream which once flowed over that spot. The constituents of the gravel were chiefly flint of various kinds, Bunter Quartzites, Quartz (one rough block measuring 10 in. × 11 in × 6 in.), Sarsens, and blocks of Rhyolite, one of which measured 9 in. × 8 in. × 4 in. Similar gravels at corresponding heights, and also characterised by the absence of Jurassic *débris*, Carboniferous Limestone, Basalt, Granite, are found all along the northern slopes of the Lower Thames Valley and to the north and west of the Stevenage and Goring Gaps. An account of these and the Director's views on them can be seen in his paper mentioned below. Filling a slight depression in the gravel near the centre of the pit was about 3 ft. of a strong clay under 1 ft. of subsoil. This was attributed to a small mud stream, and was made up of London Clay in which stones similar to those found in the gravel were mixed up.

The return walk was made through Mill Green Common, to the south of which the President and Mr. Monckton directed the party to some sand pits in which some years ago they had, for the first time in Essex, found casts of marine shells in the Bagshot Beds.

Mr. Monckton has kindly contributed the following note on these sections:—

"There are two small sand-pits in the wood north-east of the Post Office and a little west of Harding's Farm.

"The pit at the higher level of the two showed the following section:

"1. Pebbles of flint, a few sub-angular flints and one or two quartz pebbles in clay, about 1 ft.

"2. Laminated clayey bed, nearly 1 ft.

"3. Bed similar to No. 1, also about 1 ft.

"4. Yellow sand, a little more than 2 ft. exposed.

"The section is 5 ft. deep, and the beds occur in a somewhat irregular manner, and may have slipped to some extent. The pebbles and bed No. 3 seemed, however, to be below their place. The succession seemed, however, to be as above, and, if that be so, the beds below bed 1 are probably Bagshot Beds.

"The pit at the lower level has been already noticed in our Proceedings; *cf.* H. W. Monckton and R. S. Herries 'On some Bagshot Pebble Beds and Pebble Gravel,' *Proc. Geol. Assoc.*, vol. xi, p. 13, at p. 22. The pit has been worked further back, and the clay is now in consequence thicker. Less of the underlying sand is exposed than it was in June, 1888.

"The casts of shells which occur in this sand were not abundant, but several were found by members of the party on a small heap of sand at the bottom of the pit."

Similarly disturbed strata were again observed in the excavation for the new reservoir close by. A few minutes were then profitably spent in examining Fryerning Church, and its carved Twelfth Century font, etc.

At the Spread Eagle a welcome tea awaited the party, which, after thanking the Director, returned by the 7-55 p.m. train to London.

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EXCURSION TO LYME REGIS, EASTER, 1906.

FROM APRIL 12TH TO APRIL 17TH.

Directors: HORACE B. WOODWARD, F.R.S., and G. W. YOUNG, F.G.S.

Excursion Secretary: G. W. YOUNG, F.G.S.

April 12th and 13th.

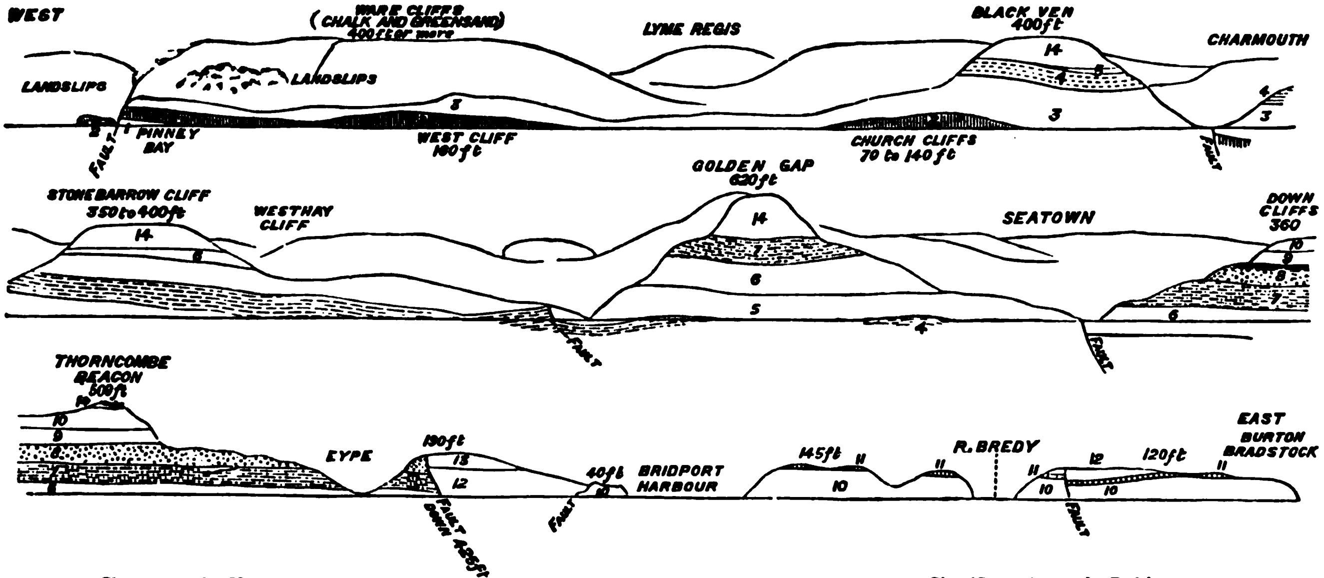
(*Report by* H. B. WOOWARD.)

SEVENTEEN years ago when the Association paid its first visit to Lyme Regis under the guidance of one of the present Directors, it was remarked that "hardly any place in the British Isles is richer in features of geological interest than Lyme Regis." The difficulties of access, and the difficulties (that naturally increase) of procuring the necessary accommodation for a large party, no doubt caused delay in visiting this classic locality, and the earlier visit was described as a "preliminary excursion."

The members then assembled at Lyme Regis on Thursday evening, April 18th, 1889, and departed on Monday morning for

SECTIONS OF THE DORSETSHIRE CLIFFS, FROM LYME REGIS TO BURTON BRADSTOCK.

Horizontal Scale one-and-a-half inches to a mile. Vertical Scale much exaggerated.



14. Chert gravel, Upper Greensand, and Gault.
13. Forest Marble.
12. Fuller's Earth.
11. Inferior Oolite.
10. Midford (or Bridport) Sands.

9. Upper Lias.
8. Sand.
7. Laminated Beds.
6. Starfish Bed. Clay with *Ammonites margaritatus*. Three Tiers (stone-beds).
} Middle Lias.

5. Clay (Green Ammonite Beds).
4. Pale-grey Marl (Belemnite Beds).
3. Dark clays and shales (Black Marl).
2. Limestones (Blue Lias).
} Lower Lias.
1. White Lias. Rhætic Beds.

the "Easter Excursion" to Weymouth.* On the present occasion the members arrived in the evening of April 12th, and made their headquarters at the "Royal Lion" Hotel, their total strength being eighty-five members and friends.

The opening of the light railway to Lyme Regis had now reduced the time occupied on the journey, since the previous excursion, from a little over five hours to about four hours, when the train was punctual. If the means of access were much better, the hills were still as steep, but there was not the same anxiety in traversing them as was felt 150 or more years ago, when, as remarked by George Roberts, the Historian of Lyme Regis, no one ever thought of journeying out of Lyme Regis without having previously made his will.†

Friday, April 13th.

On Friday morning the members started at 9.15 a.m. along the Charmouth Road past the parish church, where a memorial window to Mary Anning (1799-1847), the famous fossil collector, had been erected by fellows of the Geological Society. Thence they ascended by Colway Gate to an old chert and sand pit on Timber Hill, an elevation of about 430 ft.

The Director remarked that the term "Selbornian" (named after the home of Gilbert White), had been given by Mr. Jukes-Browne to the united Upper Greensand and Gault. The formation in the far east at Burham in Kent is all Gault clay; in the neighbourhood of Selborne both sandy and clayey divisions are well represented, while in the far west, on the Blackdown and Haldon Hills, the formation is almost wholly of the cherty and sandy type, known as Upper Greensand.

In the quarry now visited the base of the Chert-beds was to be seen, with underlying band of green sand, which rests on the main mass of Foxmould sands and Cowstones. Mention was made of the work of previous observers, full references to whom are given in the *Survey Memoir* recently published.

The following are the local sub-divisions of the Selbornian group:

			Feet.
UPPER GREENSAND.	Zone of *Pecten asper.*	Sands with bands and nodules of chert ... Greenish sands	50
	Zone of *Ammonites* (*Schloenbachia*) *rostratus.*	Buff, brown, and white sands—the Foxmould of De La Beche	75
		Cowstone Beds, sands with three bands of concretionary masses of calciferous sandstone	20
GAULT.	Zone of *Amm.* (*Hoplites*) *interruptus.*	Dark loamy and glauconitic sands and clays, with pebbly layer at base ...	25

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* See *Proc. Geol. Assoc.*, vol. xi, p. 26.

† "History and Antiquities of the Borough of Lyme Regis and Charmouth," 1834, p. 155.

Mr. W. D. Lang, of the British Museum, who now joined the party, was invited to conduct the members to the sections of Upper Greensand and Gault, which he had specially studied. The following notes are contributed by him :

1. On the cutting above the roadway between Charmouth and Lyme.

In the Foxmould = upper part of the zone of *Schloenbachia rostrata.*

Exogyra conica, Sow.
Pecten (*Neithea*) *quadricostata*, Sow.

Notes.—Both these species were very abundant, especially the first-mentioned. They are very fragmentary, and, when fairly perfect, hard to extract from the sand without falling to pieces. Three fossil beds were observed (described as beds 10, 8 and 6 in *Geol. Mag.*, 1903, p. 390), but most specimens came from the top bed (10).

It was disappointing that more species were not found, but to obtain recognisable and good specimens it is necessary to pay frequent and longer visits to the spot. Mr. A. W. Clayden observed that the fossils occurred here exactly the same way as their representatives at Haldon Hill.

2. Below the roadway between Charmouth and Lyme.

(*a*) In the Cowstones = lower part of the zone of *Schloenbachia rostrata.*

Siphonia, Sp.
Vermicularia, concava, Sow.
Exogyra conica, Sow.

Notes.—Fossils at this horizon are rare, most of those that are found occurring in the Cowstones themselves, the best known being the fossil lobsters (*Hoploparia*). From a fallen Cowstone the members obtained *Exogyra conica*, Sow., and *Vermicularia concava*, Sow., and from the sand above the lowest Cowstone layer a *Siphonia* was obtained.

(*b*) In the "Gault" = zone of *Hoplites interruptus.*

Vermicularia concava, Sow.
Pecten (*Syncyclonema*) *orbicularis*, Sow.
Lima gaultina, Woods.*
Perna tetragona, Sow.
Arca (*Grammatodon*) *carinata*, Sow.
Inoceramus concentricus, Park.
Hoplites interruptus, Brug.
Turritella vibrayeana, d'Orb.

Notes.—The "Gault" was drier than usual, and the fossils consequently less easy to extract. Nevertheless the commoner Black Ven species were soon discovered. Of these *Pecten orbicularis* was the most abundant, and after this *Lima parallela* and worm tubes. By far the most interesting find was a fragment of *Hoplites interruptus*, the zonal fossil, which has never before been recorded from Black Ven. A few fragments of *H. splendens* have been found here before, but no other Ammonite. The specimen of *H. interruptus*, and the *Siphonia* mentioned above from the Cowstone sand, are now in the collection of the British Museum.

3. On the slope below the section showing the junction of the "Gault" with the Lias, = zone of *Ammonites* (*Liparoceras*) *capricornus*, there were obtained :

Small Ammonites, being the young of *Liparoceras latæcosta*, and of allied forms.

Fragments of Belemnite guards.

Pebbles from the Pebble-bed at the base of the "Gault."

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* "The Common *Lima* found in the Gault on Black Ven, and hitherto identified as *L. Parallela*, d'Orbigny, has been shown by Woods (Mon. Pal. Soc., 1904, *Brit. Cret. Lam.*, vol. ii, part i, p. 31) not to be this species, but an unnamed form to which he has given the name *Lima (Mantellum) Gaultina.*"—W. D. L.

Notes.—Unfortunately time did not allow much collecting to be done on this slope. Usually there are to be found many kinds of Lias fossils as well as specimens of *Vermicularia concava* washed from the "Gault" and Greensand above. The Lias fossils are interesting, as they are obviously within a few feet of their exact horizon, for they cannot have fallen from above the Gault junction, a few feet higher up. Many small pieces of Ammonites, portions of larger specimens of *Amm.* (*Liparoceras*) *latæcosta*, and of *Amm. Loscombei*, as well as excellent specimens of *Straparollus aratus*, Tate, and of other species of *Straparollus* are generally to be found. About a foot below the edge of the precipice which truncates this slope, the "Belemnite stone" occurs, pieces of which some of the members succeeded in securing. This limestone was full of Belemnites, and in one piece a Reptilian bone was found.

4. Among the flints which strew the surface of the upper part of Black Ven, showing the former extension of the Chalk over the whole area, a worn specimen of a Chalk urchin was found.

While traversing the Charmouth Road the Director called attention to the great landslips that had occurred along this tract between Lyme Regis and Charmouth, conspicuous in three amphitheatre-like hollows whence the strata had broken away and foundered towards the sea-coast. On this account there were no "eligible building sites" along this portion of the sea front. The new high road made in 1825 had subsided a few years later in consequence of land slides.

A few remarks were also made on the newly-published Geological Survey Map, and on the association of the district with the great geological masters De la Beche, Buckland, and Conybeare. Allusion was also made to the work of fossil collectors, and especially to Mary Anning, who had been instrumental in discovering the *Ichthyosaurus*, *Plesiosaurus*, and *Dimorphodon* (Pterodactyl). A visit was paid to the home of Isaac Hunter, a zealous collector and dealer in fossils at Charmouth, who displayed many specimens, including a fine example of *Ichthyosaurus*.

The party now descended to the shore at Charmouth, whence a good view was obtained of the great clay cliffs of Black Ven. The mass of these clayey strata, nearly 300ft. thick, represented the zones of *Ammonites obtusus*, *A. oxynotus*, *A. raricostatus*, *A. armatus*, and *A. Jamesoni*, details of which are recorded in the Geological Survey Memoir just published.

The Director stated that anyone who desired to work at the zonal sequence should in the first instance draw a diagram of the stratigraphical divisions that are marked by prominent bands of rock, chiefly septaria or cement stones. Repeated observations were necessary, inasmuch as there were not only downwashes of greensand, but slipped masses of Lias on the cliff-fronts, and there were several faults. Moreover, the aspect of the strata varied, some layers being prominent where they had become weathered, while the harder intercalated bands were inconspicuous where masses had recently broken away. No serious collecting should be attempted until the sequence was clearly recognised.

The great difficulty nowadays was to determine the names of the fossils.

The splitting up of genera of Ammonites had long been recognised as a palæontographical necessity, but the process had been overdone, and some of the generic names applied to characteristic zonal species had been changed four or five times. Hence it seemed necessary at present to retain the name *Ammonites*, together with the other more or less temporary generic names, for the benefit of those who could not keep in touch with the repeated changes of nomenclature. Among the puzzles unsolved was the cause of variation in the shells of the Ammonites, and the reason for the incoming and domination of species that were not the modified descendants of the forms they locally succeeded. The physical conditions remained comparatively uniform, except that the more calcareous sediments of the Blue Lias were followed by the more argillaceous sediments of the Black Marl. Otherwise the circumstances did not seem to warrant a change. Some of the larger forms, such as *Am. Bucklandi* occurred in the limestone group, but other immense forms, *Am. stellaris*, were found in the cement-stone nodules in the shale group. In his address to the Geological Society, 1878, Dr. P. Martin Duncan, in referring to Ammonites, observed, " It may be reasonably doubted whether the different ornamental and septal details are the evidence of a struggle, for it does not appear that they are of any vital importance."* It is fortunate that the variations are of so much geological value.

Mr. E. T. Newton then made some remarks upon certain of the commoner forms of Ammonites which occur near Lyme Regis. He would not undertake to explain the new generic names which had been given to these species; indeed, he agreed with the Director that it was difficult to say which name was the right one. Mr. Newton, however, explained some of the more salient features of the species from the Lower and Middle Lias which members had obtained, or were likely to find, during the excursion.

The Director pointed out that while the different species of Ammonites, as observed by Mr. Hudleston, are excellent " time-keepers," this was not the case with other forms of Mollusca that locally characterise horizons, such as *Cardinia*, *Hippopodium*, etc.

Some criticisms were made on the names locally applied to the main divisions of the strata—more especially to the " Green Ammonite beds." More appropriate names for local use would be the Lyme Regis Beds for the Blue Lias, the Black Vent beds for the Black Marl, the Charmouth Beds for the Belemnite beds and Green Ammonite beds. Unfortunately the name

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* *Quart. Journ. Geol. Scc.*, vol. xxxiv (Proc.), 68.

† The name Black Ven beds was used at one time by C. J. A. Meyer for the Gault. *Geol. Mag.* 1866, plate II.

"Charmouthian" had been applied as a chronological division to the Zones from *Am. armatus* to *A. spinatus*, thus including part of the Lower and the whole of the Middle Lias, a grouping not justified locally.

Turning to the broad local divisions, the Director pointed out that the pale grey Belemnite beds on which the Gault of Black Ven for the most part rests, form the upper of three clay terraces in that cliff, and also the more conspicuous portion of the Stonebarrow cliffs east of Charmouth. The mass of Black Ven was composed of the underlying dark shales and clays, with here and there a band or nodular layer of limestone. In these strata occur the "Watch stone beds," with fine examples of *Am. raricostatus*, also the metal-bed with much pyrites, the decomposition of which had given rise to the spontaneous combustion of bituminous shales. *Am. oxynotus* occurred lower, and then come beds with *A. Brookei*, *Extracrinus briareus*, *Am. Birchii*, and many small Ammonites.

Some remarks were made by Dr. Smith Woodward on the fish fauna of the Lower Lias, which includes *Acrodus*, *Hybodus*, *Dapedius*, and *Pholidophorus*.

The Director observed that many who come to Lyme Regis for a short time are apt to be disappointed in not easily finding *in situ* fine examples of fossils. Such specimens were not to be obtained readily, except perhaps in the cottage of Isaac Hunter at Charmouth. Time and labour were necessary in this as in most other famous localities for fossils, Many of the better specimens had been obtained from fallen blocks. It was hoped that the particulars of the strata given in the Survey Memoir might prove a basis for further detailed work, of which there was much to be done. We knew little of the precise horizons of the fishes, and the same might be said of the plant remains, although, as remarked by Mr. A. C. Seward, the majority of the British Liassic plants had been obtained from the Lower Lias at or near Lyme Regis.*

Despite the difficulties in collecting and in naming fossils, it was a comfort to read the stimulating words of the ex-President, Dr. A. S. Woodward, in his address of 1905. He then remarked, "The collector of fossils, in any case, even if he be confined to one small district, is just as important now as he ever was for the progress of Palæontology. The only difference is that, whereas in former days his chief interest centred in filling a cabinet with choice specimens, his present aim should be rather to illustrate certain definite problems and principles which modern research has formulated."

The members now proceeded along the shore in front of the Limestone series of the Church Cliffs.

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* Catalogue of the Mesozoic Plants in Dept. Geol., British Museum. "The Jurassic Flora,' II, 1904.

Attention was called to the varying nature of certain layers; some known as "skulls" mimicking chalk-flints in the irregular character of the nodular bands, while in other cases there occurred smooth lenticular or ovoid masses of Limestone. This process of segregation of the more calcareous matter from the mud might have varied according to the pressure to which the bands were subjected by overlying deposits during consolidation. The Director maintained that the Limestone was largely detrital, derived not mainly from the grinding up or decay of the organic remains of the period, but largely from the waste of Limestone cliffs that bordered the Liassic seas.

Mr. A. W. Clayden remarked that he had always considered the Lias Limestones to be of detrital origin, as it seemed impossible to account for the alternating layers of Shale and Limestone on any other hypothesis. If we imagine the calcareous matter to be an organic deposit in a clear sea, we need a succession of alternating climates, which seems impossible, whether we attribute them to geographical or meteorological changes. The source of the calcareous matter would appear to have been most probably an eastward extension of the coral archipelago of Devonian times, the westward end of which is seen in Devon. This would be a more probable source of the Lyme Regis Limestones than the Carboniferous Limestone, as that formation under Dorsetshire would be more likely to resemble the Culm Limestones of Devon than the massive structures of the Mendips.

The Limestone series of the Church Cliffs included the zones from *Ammonites angulatus* to *A. semicostatus* (with *A. turneri*, as recorded by Dr. Wright), the upper limit being taken at the Hard Marl or Table Ledge, a conspicuous band (a little above the main mass of Limestones), which descended to the sea-shore at the foot of Black Ven.

The Director made a few remarks on denudation or erosion, due to subaerial, marine, and human agencies. Buckland, observing that the hills and valleys were abruptly terminated by the sea, recognised that marine action had no share in shaping them, and he had inferred that as the present streams appeared inadequate, diluvial waters had performed the task. With this view the Director was disposed to agree, to the extent that torrential action during the Glacial period had probably been a potent cause in the excavation of the valleys.

The waste of the coast by marine action was sufficiently evident, and it was mentioned that remnants of valley drift, with Mammoth and Rhinoceros, had existed on the lower part of the Church Cliffs in the early part of last century. This was, no doubt, a portion of the old valley of the Char, now obliterated by the encroachment of the sea.

The platforms of Limestone-rock exposed at low tide formed a plain of marine erosion. East of the Church Cliffs, where the general dip of the Limestone strata was easterly, the bay had been excavated in the softer overlying clays and shales.

The hand of man had, however, grievously aided the destruction of the coast by the quarrying of the Limestone, and, as George Roberts had stated, by the tearing up of reefs and ledges on the foreshore, a process that has not been altogether abandoned.

A few remarks were made on the Lower Lias as a source of water supply; as a rule it yields only limited supplies near its outcrop. The great water-bearing strata of the district were the chert-beds and sands of the Upper Greensand, and from springs that issue from these strata, a little to the north of Timber Hill, Lyme Regis derived its supply.

The members eventually proceeded by the Gun Cliff to the Esplanade, and thence to the end of the Cobb.

April 14th.

(*Report by* H. B. WOODWARD.)

Starting at 9.15 the members were driven through Charmouth to Morecombelake.

The party was then conducted towards the summit of Hardown Hill, where in a lane-cutting the Director called attention to a fossiliferous band in the Foxmould sands beneath the chert-beds, which he had noted two years previously.

He observed that here, as in the case of the silicified fossils of the Blackdown Beds, the mineralisation was due probably to the decay of the overlying chert-beds and the transmission of soluble silica to replace the calcareous shells.

A number of the members were soon busily engaged in collecting fossils, and the following report of the results is kindly supplied by Mr. W. D. Lang:

1. A section in Verriott's Lane, north-east of Morecombelake, near the top of Hardown Hill, at about 540 ft.

In the Foxmould = upper part of the zone of *Schloenbachia rostrata*.

Exogyra conica (Sow.).
Exogyra, plicate form.[*]
Exogyra canaliculata (Sow.).
Pecten (*Neithea*) *quadricostata* (Sow.).
Ostrea, cp.
Serpula filiformis (Sow.).
Entalophora ramosissima (d'Orb.).

Notes.—As on Charmouth Cutting on Friday *Exogyra conica* and *Pecten* (*Neithea*) *quadricostata* were by far the commonest species. In addition to these two, *Exogyra canaliculata*, two or three of plicate form, a few *Serpula filiformis*, and a few fragments of *Entalophora ramosissima* were found. All

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[*] "Wrongly identified as *Exogyra plicata* (Lamarck) in *Geol. Mag.* 1903, p. 391. Lamarck's *Ostræa plicata* is not an *Exogyra*. This plicate *Exogyra*, occurring with *E. Conica*, Sowerby, is figured by d'Orbigny (1846, *Ter. Crét.*, vol. iii, pl. 478, figs. 5 & 6) and by Coquard (1869, Monographe du Genre *Ostræa*, Terrain Crétacé) as identical with *E. Conica*. Mr. R. B. Newton, who has kindly examined the Black Ven specimens recorded in *Geol. Mag.* 1903, considers that the smooth specimens of *E. Conica*, Sowerby, have lost the plications through wear and that they are only present on young shells."
—W. D. L.

these species have been obtained rarely in Charmouth Cutting, but the Association members were not fortunate enough to find them there on Friday.

2. In a parting of sand between beds of chert on the top of Hardown Hill at a height of more than 600 ft. In the zone of *Pecten asper*: *Rhynchonella*, sp.

In addition to the fossils already mentioned:

3. A single fish-vertebra was found near the chert quarry at the top of Hardown Hill in the zone of *Pecten asper*. An urchin was found in flint among those strewn about the top of Hardown Hill. The chert itself when weathered was often seen to consist of sponge-spicules.

The party now ascended to the summit of the hill, about 600 ft. (the highest point is 677 ft.), and attention was drawn to the chert-beds which had been quarried in many places for road metal. Here, as in a small quarry seen on the previous day near the Charmouth road-cutting, the dark and pale chert was in places much decomposed. It appeared to pass into a kind of white silica sand, a powdery material subsequently ascertained by Mr. H. H. Thomas to consist of finely divided silica. Associated with the decomposed rock there was a greenish sand and manganese-ore. A microscopical examination by Mr. Thomas of the material showed the presence of staurolite, of abundant tourmaline, of rutile, and a little cyanite. These mineral ingredients, as he has remarked, might be derived from the Triassic rocks, or directly from the parent source, in the region of Dartmoor.

Attention had been directed by Mr. Jukes-Browne to the disintegration of the chert-beds on this hill and to the settling down in mass of the harder portions, while the softer intervening materials were washed away by rain and springs.* The result has been to produce an appearance of "broken beds." Resting irregularly on the shattered chert-beds was an accumulation of whitish clay with sub-angular flints and chert and pebbles of quartz and quartzite, which occurred here and there on the flat-topped plateau. In the opinion of the Director this was a remnant of the accumulation similar to that observed by him at Combpyne, and referred to the Bagshot Beds.

From the summit of Hardown Hill a fine view was obtained eastwards towards the Dorsetshire Downs and Portland, and it was mentioned that Mr. Clement Reid had pointed out the overlap of the Bagshot Beds beyond the limits of the older Eocene strata, when traced from east to west in Dorsetshire.† The gravel on Blackdown Hill (Hardy's Monument), above Portisham, referred by Mr. Reid to the Bagshot Series, was about thirteen miles distant from Hardown Hill.

In the intermediate area the land had been extensively eroded, and where unprotected by hard cappings of Inferior Oolite or Greensand chert, the hills of Bridport Sands or Middle Lias or Upper Greensand stood out as rounded knolls.

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* "Cretaceous Rocks of Britain," vol. i, p. 191.

† *Quart. Journ. Geol. Soc.*, lii, 492.

The flat-topped hills that characterise the uplands were regarded by the Director as belonging mainly to a plain of subaërial erosion that had been intersected by the Eocene river and its tributaries (referred to by Mr. Reid). The actual distribution of the Eocene accumulations had yet to be determined, and this would form an interesting subject for investigation.

The extensive distribution of chert-detritus ("run of the hill") over the slopes bordering the valleys was well seen in the lane-cutting traversed in ascending the hill.

Discussing the question of mapping the soils, the Director pointed out that if the cherty soil were mapped it would afford little indication of the true agricultural value of the land, as it sometimes coated the Foxmould Sands, elsewhere the stiff Liassic clays, and farther west the Keuper Marls. It was most important to the agriculturist to know the nature of the subsoil or underlying geological formation.

The uplands formed heath-lands and tracts under tillage; the vales were for the most part grass lands and orchards, the vale of Marshwood being a district celebrated for Dorset cheese, butter, and cider. Reference was made to Mr. Jukes-Browne's views on the Origin of the Vale of Marshwood, as influenced by the domelike or pericline structure exhibited by the strata.

Allusion was also made to the great accumulations of gravel that occur here and there in the valley of the Axe, as at Broom, between Chard Road station and Axminster, where palæolithic instruments fashioned out of chert had been obtained. Mr. F. W. Rudler kindly exhibited a specimen.

Much later evidences of man's existence, but still prehistoric so far as our own literature is concerned, were the earthworks that crown most of the prominent heights in the district—Hawkesbury, Musbury, Membury, Lambert's Castle, and Pillesden Pen. These take us back to early British times, to conflicts among various tribes, and to the Roman occupation.

Prof. Boyd Dawkins then gave an interesting address on the ancient inhabitants of Dorset, and on the prehistoric roads.

He pointed out that the population in the Neolithic Age were a small, dark non-Aryan stock, closely allied to the Iberians, whose features and complexion and physique generally are still possessed by the present inhabitants of Dorset and the south-western counties. They were followed by the tall, fair, bronze-using Goidels who represent the older branch of the Celtic race, whose language still survives in place names, such, for example, as Maiden Castle, near Dorchester (Magh=field, Dun = fortress), and the Cop (Gop=headland), and in river names, such as Axe and Exe. They in turn were invaded, in the Prehistoric Iron Age, by their Celtic cousins the Brythons, who have left their name in the island of Britain, and their language in innumerable place names in this district, such, for example, as Combe (Cwm) and Dor (Dwr) in "Dorchester" The population of this part of the country before the Roman conquest consisted of these three elements intermingled together.

The population was mainly massed on the hills and higher and drier ground, because the valleys were covered by forests and impenetrable morasses. Their forts and villages were connected by roads along the lines of the ridges, constituting the ridgeways. These were at first tracks in the Neolithic Age; they were further developed in the age of Bronze, and in the prehistoric Iron Age were well-defined roads, which have been in use in many places ever since. They are distinguished by their winding course from the point-to-point Roman roads. The so-called "Roman Road" in this district was merely one of those used by the Romans.

The members now descended the hill, and proceeded by the Saints' Well (so marked on the Ordnance Survey map), where Professor Dawkins made some remarks on Holy Wells. The spring issues from the base of the Greensand, being thrown out either by Gault or Lias clay. Thence, by lane and footpath, the route was by the old village of St. Gabriel's, with its ruined church, to the sea-shore at Gabriel's Mouth. Here the little stream, after having cut a deep chine in the Lias clays, filters through the bank of shingle, and issues about mean-tide level.

The Director remarked that the cliffs to the west, at Stonebarrow and Westhay, showed the pale grey Belemnite Beds and overlying Green Ammonite Beds surmounted by the Greensand.

Golden Cap, which rises to a height of 619ft., was based on the Belemnite Beds, which were well shown at low tide beneath the highest portion of the cliffs, and they appeared at intervals, owing to undulating and small faults, in the cliffs a little above the level of the shingle, as well as in places between tide-marks where the shingle had been scoured away.

The lower cliff above the Belemnite Beds was formed of the marly clays of the Green Ammonite Beds, so named from the green-tinged calc-spar which often fills the chambers of the characteristic Ammonite (*A. latæcosta*); a feature well seen in cut and polished specimens.

Above the Green Ammonite Beds occur three bands of hard calcareous sandstone known as the "Three Tiers," which constitute the base of the Middle Lias, and form a prominent feature in Golden Cap.

Tumbled blocks have made a kind of headland mid-way between Gabriel's Mouth and Seatown, where the cliffs present their most impressive appearance, and where more tiers have been shed than at any other point along the coast. The dark Liassic clays and above them laminated clays and sands, and a hard band known as the Starfish Bed (part of the Middle Lias) rise to a little over 400ft., and these are surmounted by the pale buff and brown sands and chert-beds of the Upper Greensand, with a capping of flint and chert gravel. In wet weather streams of Liassic mud, both here and at Stonebarrow, slowly descend like mud-glaciers, while the chines and hollows are bordered by fantastic projections and peaks of the clay-cliffs. The erosion is marked; in due course Golden Cap will be lost, and Hardown Hill may replace it along the future coast-line.

Many Belemnites (*B. longissimus*, *B. elongatus*, *B. clavatus*, *etc.*) were to be seen in the Belemnite stone and underlying shales, while in the overlying marls *Ammonites latæcosta*, *A. loscombei*, *A. striatus*, and other fossils were obtained.

Tea was provided at the "Anchor Inn," at Seatown, after which some of the members crossed the little stream to examine the base of Down Cliffs, where the Middle Lias Clays with *Ammonites margaritatus*, that occur above the Three Tiers, were depressed by a fault to sea-level.* The party was then driven back through Chideock to Lyme Regis.

In the course of the evening Dr. Smith Woodward gave an eloquent and instructive address on the evolution of the Liassic Saurians.

April 15th.

(*Report by* H. B. WOODWARD.)

A small party started at 10 a.m. up the valley, by the borders of the little river Lym or Buddle, and past the site of the deep boring made for coal during 1901. This was on the left bank of the river, west of Colway Manor House. The boring was superintended by the late G. Haycraft, and it was carried to a depth of 1,302 ft., through about 173 ft. of Gravel, Blue Lias, and Rhætic Beds, and 1,129 ft. of Keuper Marls, with beds of gypsum. Full particulars had been published by Mr. Jukes-Browne.† Some of the cores were seen in an old cottage by Middle Hill Farm.

Passing Uplyme Mill, the members proceeded by pleasant lanes and footpaths to Uplyme Church and the Yawl limekilns. Here the lower beds of the Lower Lias (zone of *Ammonites planorbis*, and portion of that of *A. angulatus*) were exposed, with the White Lias below. A few fossils were obtained, including *Ostrea liassica*, *Pleuromya*, and *Ammonites conybearei.*

After lunch the members proceeded again by footpath and lane to Wadley Hill, and thence, west of Holcombe, ascended the slope between the 400 and 500 foot contour-lines.

Here an unusually deep and dry gully attracted attention. It traversed the Greensand scarp above the level of the usual outlet for springs, as is the case with other stream-channels on the Greensand uplands. It was remarked by the Director that in heavy rains the waters held up by the clayey plateau drifts rapidly descend the slopes; but that the permanent springs are given out at the base of the Greensand. In the present instance the

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* A visit was paid to Seatown at Easter, 1898. See *Proc. Geol. Assoc.*, vol. xv, p. 293.

† *Quart. Journ. Geol. Soc.*, vol. lviii, p. 279.

LYME REGIS (RAIN GULLEY), WEST OF UPLYME (LOOKING DOWN HILL).
Photo by W. P. Young.

PINHAY BAY, WEST OF LYME REGIS (BLUE AND WHITE LIAS).
Photo by H. W. Monckton.

Easter Monday, April 16th.

(*Report mainly by* G. W. Young.)

In brilliant sunshine the party, reinforced by some visitors from Exeter, left the hotel at 9.15 a.m. under the leadership of Mr. G. W. Young, and proceeded along the Axmouth Road. Just beyond Cobb Road they took the path across the fields leading to the Warren. At the top of a steep ascent a fine view was obtained over the town and harbour. Here a halt was made, while the Director pointed out the physical features of the district.

Lyme Regis is situated in the trough of a gentle local syncline which carries down the limestones forming the base of the Lower Lias (Blue Lias) below sea level. These hard beds form the cliffs east and west of the town, while between them the valley of the Lym or Buddle has been excavated in the softer overlying Black Marls. The higher parts of the hills are of Upper Greensand, which immediately to the west is capped by a small outlier of Chalk, which latter was to be examined presently in detail. Overlying both these formations and forming the highest ground is a mass of "Clay with flints and chert." A glance at the newly-published One-inch Geological Map (Sheets 326 and 340) shows how closely the boundaries of this clay follow the outcrop of the Cretaceous Beds, the latter indeed sometimes appearing as a mere fringe around the clay. Each ridge and spur had its capping of clay, and the speaker thought it a good example of the protection afforded by "clay-covers" to porous beds which lie beneath them.

Going from east to west a remarkable over-step of the Upper Cretaceous Beds was found.* At Thorncombe Beacon, near Bridport, they lie on the Midford Sands, at Golden Cap on the upper beds of the Middle Lias, at Stonebarrow Cliff on the lower beds of the same, at Black Ven on the Belemnite Beds of the Lower Lias, at Pinhay on the Black Marls, and at Haven Cliff (Seaton), and beyond on the Keuper Marls of the Trias. As far as Beer they dip gently westward, while the underlying beds have a slight easterly dip, accentuated here and there by faults. West of Beer all the beds dip eastward, while at Beer itself there is a sharp syncline, evidently connected with the well-displayed fault at Seaton Hole.

Mr. Young next gave a short account of the way in which the Chalk had been divided by various authors, culminating in the zonal system now in vogue. In comparison with other districts the Chalk here is remarkably thin, being only 223 ft. thick (at Pinhay). Eastward, near Lulworth, it is 1053 ft. thick, but it is noteworthy that the thinning is due, not to the attenuation of the

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* See Mr. H. B. Woodward's Sections, p. 321.

individual zones, but to the entire absence of others.[*] The zones present are those of:

		Feet. exposed.	
UPPER CHALK.	*Micraster cor-testudinarium*	50	
	Holaster planus	39½	
MIDDLE CHALK.	*Terebratulina gracilis*	71½	? possibly rather more.
	Rhynchonella cuvieri	59½	
LOWER CHALK.	Cenomanian limestone	3	
		223½	

The higher zones are absent, but near Lulworth they amount to 768½ ft. in thickness. Whether they were all once present is a matter for conjecture, but great denudation has certainly taken place. Flints containing fossils from some of these vanished zones are occasionally found on the surface. The Lower Chalk is represented only by the Cenomanian limestone, 2 to 3 ft. in thickness.

The party then proceeded through the Warren, a picturesque undercliff of broken ground lying at the foot of the inland Ware Cliffs. These are of Chalk and Upper Greensand, but are much overgrown and inaccessible. The face is almost obscured by the down wash of the clay with flints, but here and there patches of Chalk peep out. The Warren was a beautiful sight owing to the profusion of primroses and other wild flowers, and the woods were white with the blossom of the blackthorn and wild cherry.

The first available exposures of Chalk, the Pinhay Cliff and Chapel Rock, are situated in the grounds of Pinhay (formerly known as Clevelands), the residence of W. Allhusen, Esq., who had not only given permission to examine them, but had invited the whole party, 88 in number on this day, to luncheon and tea. At this spot the members were joined by Mr. and Mrs. Allhusen and some of their family, who took great interest in the subsequent proceedings.

The sections at Pinhay have been so well described by Dr. Rowe in the paper alluded to that little need be said here. The zones exposed are those of *Micraster cor-testudinarium*, *Holaster planus*, and *Terebratulina gracilis*, the latter in the main cliff only. The Chalk of the two first-named zones is hard and extremely nodular, weathering with a deeply fretted surface. The zonal junction lines and other salient features were identified, and considering the short time at disposal a satisfactory collection of fossils was made. These included some *Micrasters*, showing the typical variations proper to the zones in which they were found.[†] The members next repaired to the house, where a sumptuous luncheon was done full justice to.

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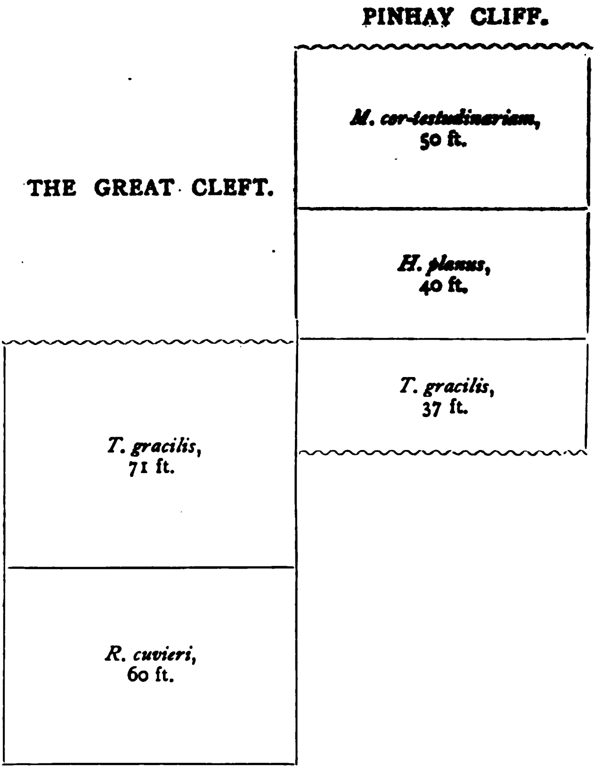
[*] The following account is largely based on Dr. Rowe's admirable paper on the Chalk of this coast. See *Proc. Geol. Assoc.*, vol. xviii, p. 3.

[†] See Rowe, *Quart. Journ. Geol. Soc.*, vol. lv, p. 494.

After luncheon the way was taken westwards along the top of the cliff past the Chapel Rock. Seen from above the place from which it has slipped is very evident. On arriving at the Great Cleft Mr. Young gave a short account of its formation. It is a fissure running parallel to the face of the cliff, thus cutting off a thick slice of rock. The crack first started in 1886, had gradually widened year by year, but rather more rapidly of late than at first. The base is cut in Upper Greensand, the cherty nature of which was well displayed. Many fossils could be seen, but were somewhat difficult to extract. Next came the Cenomanian limestone (Lower Chalk), about 3 ft. thick, and then Chalk of the zone of *Rhynchonella cuvieri*, 60 ft. thick, followed by 71 ft. of *Terebratulina gracilis*-zone.

The relative position of the beds at the Cleft with those at Pinhay Cliff are shown below.



Particular attention was drawn to the abnormally flinty character of the *T. gracilis*-zone, which as a rule contains but few flints while here they are very abundant. To those who rely on lithological characters this would prove a stumbling-block, as they would naturally class it as Upper Chalk, but the fossils are a surer guide, and are unmistakably typical of this zone.

Mr. Newton then explained that the so-called "*Terebratulina gracilis*-zone" could no longer be called by that name, because the small Brachiopod there found was not the true *Terebratulina gracilis*, but another form, the true *T. gracilis* only having been met with in the higher beds of the chalk at Trimmingham, in Norfolk. The *Terebratulina* found in the Middle Chalk seemed to be the form named *Ter. lata* by Etheridge, but this required further examination. It was best, for the present, therefore, to call this zone of the Middle Chalk simply the "*Terebratulina*-zone."

Mr. Newton also spoke of the differences found in the genus *Micraster*, and explained (to some extent by means of specimens found during the excursion) how that in the lower bed of the Upper Chalk (lower part of *Holaster planus*-zone), and just below this, in the Middle Chalk, Micrasters were found which had the ambulacral grooves smooth or finely granular (*M. corbovis* and *M. leskei* were of this type), but this character was never found above the *H. planus*-zone. High up in this zone and extending into the *M. cor-testudinarium*-zone, there were *Micrasters* with ambulacral areas showing a zig-zag natural line, and this line became more and more marked in the *Micrasters* found in the higher parts of these zones, until in some cases the angles formed a series of rounded knobs. All these forms would be included in Dr. Rowe's *M. præcursor*, the more strongly marked being difficult to separate from the *M. cor-testudinarium*. Still higher in the chalk these suture lines were marked by a straight and deep groove, such as characterised *M. cor-anguinum*, the species which had given its name to the next higher zone. Other characters accompanied these changes in the ambulacral areas in *Micraster*, and one of these was the increased tuberculation of the entire test as we pass from lower to higher zones. With these characters of the *Micrasters* Dr. Rowe has shown us that it is possible to recognise most of the zones of the Upper Chalk.

The party then divided, those who wished to have longer time on the shore going down with Mr. H. B. Woodward, whilst those who were returning to Pinhay for tea began collecting fossils in earnest. Most of them scrambled up through the cleft to the top, and were rewarded by finding many characteristic fossils, especially *T. gracilis*, which were plentiful and well weathered out.

After tea the President moved a cordial vote of thanks to Mr. and Mrs. Allhusen for their very kind hospitality, which was carried with acclamation, and then a descent was made to join the others on the shore in Pinhay Bay.

Here Mr. Woodward took charge of the party, and explained that east of the ravine along which the descent was made to the shore, the White Lias was well seen beneath the Blue Lias, dipping gently eastwards until it disappears beneath sea-level. The ravine coincides with a fault, having a downthrow of about 40 ft. on the west. This dislocation brings the Lower Lias against the White Lias, and there is another small fault a little farther east.

On the present occasion the members were fortunate in finding some good exposures of the black *Avicula-contorta* shales on the foreshore, and examples of *A. contorta*, *Cardium rhæticum*, and *Pecten valoniensis* were obtained. The Cotham Marble was not exposed, owing no doubt to coverings of beach shingle and boulders. It had been observed at Charton Bay and Culverhole, near Axmouth.

Professor Boyd Dawkins pointed out that the Black Shales of the *Avicula-contorta*-zone on this coast are physically identical with those which he studied many years ago in West Somerset, at Blue Anchor, Watchet, and the adjacent coast.* The same holds good with regard to the White Lias.

The Rev. H. H. Winwood also made a few remarks in reference to the labours of Charles Moore, who first worked out the fauna of the White Lias.

On the route along the shore to Lyme Regis the various bands of Lower Lias, from the basement beds with *Ostrea liassica* to the zone of *Ammonites Bucklandi* were successively traversed. Numerous fossils were to be seen, notably *A. Bucklandi*, *A. Charmassei*, and *Nautilus*. Many examples of *A. semicostatus* were observed in blocks that had fallen from higher portions of the cliffs, and some of these fossils appeared to occur in chambers of large Ammonites.

Further on by West Cliff the tumbled blocks of rock are utilised for the lime-works, and when necessary portions of the cliff have been blasted to obtain limestone for the kilns.

Along this part of the coast the Blue Lias Limestone-series, which comprises about 100 ft. of strata, can be best studied in detail. It is, however, desirable to keep at a little distance from the cliffs between Pinhay Bay and Devonshire Point, as small and large blocks are liable to fall at any moment.

In the evening after dinner the President moved the usual votes of thanks to the Directors, and also to Mr. G. W. Young, in his capacity as Secretary to the excursion.

April 17th.

(*Report by* H. B. WOODWARD *and* G. W. YOUNG.)

The members proceeded by train at 9.40 a.m. to Combpyne Station, and thence walked to Charton. Here Mr. C. W. Grover, who had assisted in the previous excursion of the Association to Lyme Regis, joined the party with his son, and offered on behalf of the Hon. Lady Peek and Sir Wilfrid Peek a welcome to the members, and permission to wander over the lands of Rousdon.

The party then descended by Charton Goyle to Charton Bay,

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* *Quart. Journ. Geol. Soc.*, vol. xx, 1864, p. 396.

where a fine section was seen of the Grey Marls that occur beneath the Black Rhætic Shales and above the red and variegated Keuper Marls. These Grey Marls have formed a debatable ground between Rhætic and Keuper, and they may appropriately be regarded as passage-beds.

Attempts to find the bone-bed *in situ* were not successful owing to slips, but some slabs with fish-remains were picked up.

Mr. Grover and his son then conducted the members towards the great landslip, but a halt was first made for lunch that had been prepared in the broken ground east of the cliff cottage, Dowlands.

After lunch the party divided, some accompanying Mr. G. W. Young to the top of the inland cliff at Dowlands in order to see the landslip from above. After examining an exposure in the *T. gracilis*-zone, where the representative fossil was found in astonishing abundance and beauty, a walk along the cliff edge afforded a most impressive view of the chasm. The great size of the slipped mass and the nature and extent of the slipping can perhaps be better realised from above than from below. Noticeable also at the east end are some detached masses, of which those that are capped with turf at the summit have the flat top of their original surface, while others which have lost that protection are worn to a knife edge. Descending the cliff by a steep path they rejoined the main party which by that time had assembled in the chasm, having been conducted by Mr. A. W. Clayden.

Mr. Woodward then gave a brief account of the landslip, the effects of which had been so beautifully depicted by Mrs. Buckland in the great *Memoir* written by W. D. Conybeare and William Dawson, with the co-operation of William Buckland, in 1840. Two copies of this work had been exhibited at the hotel at Lyme Regis, one having been kindly brought by Mr. Clayden.

At the western end of the landslip* the cliff path was taken, and here Mr. H. B. Woodward, who was returning to Lyme Regis, took leave of the party amid a spontaneous and hearty burst of cheering. A short walk across the golf links on Haven Cliff ending in a descent past the coast guard station, brought the members to the mouth of the River Axe, with Seaton station just beyond.

There being plenty of time before the departure of the train, Mr. Whitaker, indefatigable as ever, led a party to examine the Triassic Marls at the base of Haven Cliff, while Mr. Young pointed out to the remainder the position of the conspicuous fault at Seaton Hole, and the sharply dipping-beds of the Beer

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* The Excursion at Easter, 1899, advanced eastwards as far as this point. See *Proc. Geol. Assoc.*, vol. xvi, p. 134.

syncline displayed in the bold headland of Whitecliff. The abrupt easterly bend of the River Axe just as it reaches the beach, due to the shifting of its mouth, caused by the travel of the shingle, was noted and commented on.

Reassembling at the station the 3.52 p.m. train was taken and the proceedings terminated.

The unbroken fineness of the weather, the diversified beauty of the coast, the interesting character of the geology, and the large numbers attending, all contributed to make this excursion a great success.

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EXCURSION TO EAST WICKHAM AND BOSTAL HEATH.

SATURDAY, APRIL 28TH, 1906.

Directors: A. L. LEACH AND B. C. POLKINGHORNE, B.Sc.

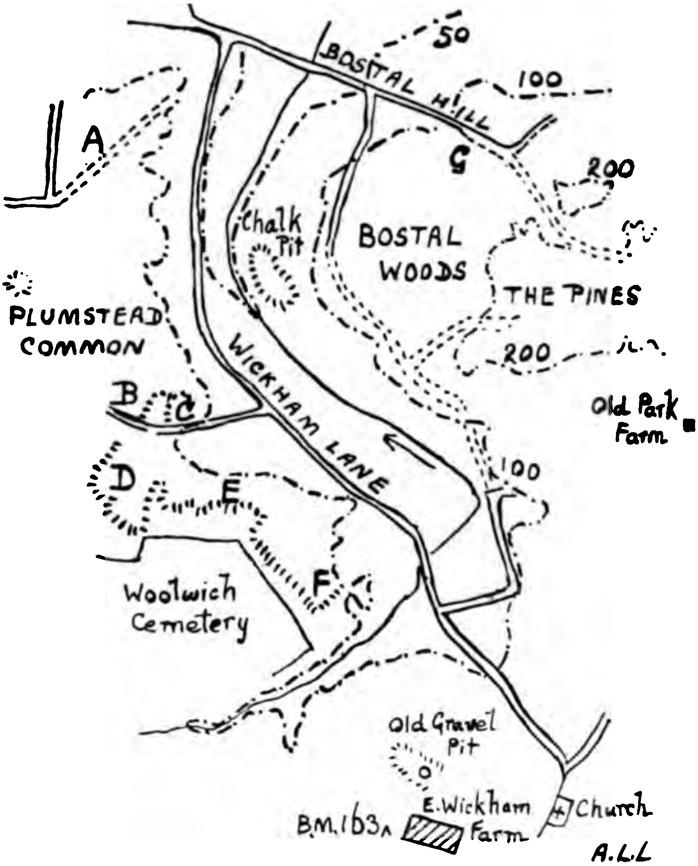
Excursion Secretary: A. C. YOUNG, F.C.S.

(*Report by* THE DIRECTORS.)

THE party, numbering 23, met at Plumstead station, at 2.30 p.m., and proceeded by way of the High Street and Lakedale Road ("Cage Lane" in the *Geol. Surv. Memoir*) to Plumstead Common, where the first halt was made at the north-eastern corner of the common beside the path leading to Wickham Lane. In reference to former excursions the Directors remarked that the district was first visited by the Association in July, 1887, under the Directorship of the late Mr. J. G. Goodchild. Some of the sections then examined have long since been covered by the rapid growth of Plumstead, but the exposures now open are as good as, if not better than, any series formerly accessible, and exhibit very fully all the strata between the Chalk and the London Clay, together with good sections in the Pleistocene Brickearths of the Wickham Valley. The 1887 excursion is fully reported in the *Proceedings;* subsequent visits in 1894 and 1901 are only briefly recorded.

The Directors then drew attention to the chief features of interest in the geology of the district. To the north lay the broad valley of the lower Thames, the river itself being seen over the wide belt of alluvium which forms the marshes of Erith and Plumstead. Rising nearly 200 ft. above the marsh-land the Lower Tertiaries form the pebbly plateau on which Bostal Heath, Plumstead Common, Woolwich Common, Blackheath, and Greenwich Park stretch for 7 miles as an almost continuous belt of heath and common land. The edge of this plateau was seen to be crenated by valleys in every stage of formation: some mere hollows in Blackheath Beds, others cut down through the Woolwich loams (*e.g.*, The "Slade"), or into the Thanet Sand, the more advanced stage being exemplified in the East Wickham Valley, which is practically an adult "combe" with a permanent stream that has eroded its bed through London Clay and the Lower Tertiaries down to and into the Chalk.

From the point where the members were assembled, successive sections could be traced, showing Chalk in the floor of the valley, Thanet, Woolwich, and Blackheath Beds on the slopes; about a mile to the south-west the London Clay mass of Shooters Hill stood out prominently. Attention was drawn to the enormous amount of denudation accomplished between the deposition of the sands and gravels on the top of Shooters Hill



CONTOURS OF THE EAST WICKHAM VALLEY. THE LETTERS DENOTE THE SECTIONS VISITED ON APRIL 28TH, 1906.

A.	Section	at N.E. corner of Plumstead Common.
B.	,,	near Hope Cottage.
C.	,,	in Jenner's Chalk and Sand pit.
D.	,,	"Cemetery" Brickyard.
E.	,,	South Metropolitan Brickyard.
F.	,,	Gregory's Brickyard.
G.	,,	Road cutting on Bostal Hill.

and the formation of the Pleistocene brickearths in the Wickham Valley, 350 ft. lower down.

After this general survey of the Geological position the following sections were examined in detail:—

(A.) Section near Bartlett's Hollow; (B.) Hope Cottage; (C.) Jenner's (Hoar's) Chalk Pit; (D.) "Cemetery" brickfield; (E.) South Metropolitan brickfield; (F.) Gregory's brickfield.

(A.) Here the Blackheath Beds were well displayed. A thick pebble-bed, showing great variation in the size of the pebbles, rested in a series of "scoops" upon a set of false bedded sands and gravels which, in turn, lay on an eroded surface of the Woolwich Shelly Clays.

The party now walked along the eastern edge of Plumstead Common, passing some wooded "combes," to the large sand-pit opposite Hope Cottage (B.), where the Blackheath Pebbles were seen cutting down into the Woolwich bottom bed (as at Abbey Wood). The section, recorded by Mr. Whitaker many years ago, is as under:

Section near Hope Cottage.

12ft. Blackheath Beds: A little laminated Clay at base.
10ft. Woolwich Beds: Greenish sand—clay at top—scattered pebbles at bottom.
56ft. Thanet Sand: Fine white sand—clayey near base.

A few yards lower down King's Highway, in Jenner's (Hoar's) pit, section (C) showed:

Section in Jenner's Pit.

0 to 10 ft. Drift: Fringe only of the main deposit in the valley.
50 ft. Thanet Sand: Cut off the east by "Drift."
1 ft. "Bull Head": Irregular.
12 ft. Chalk.

The "Bull Head" or "bed of greencoated flints" at the base of the Thanet Sand, attracted much attention. The typical flints were found and Dr. A. E. Salter detected a large flattened ferruginous concretion, an unusual constituent of this bed, but perhaps most interest was excited by the remarkable change in the junction of the Chalk and Thanet Sand. On the northern side of the pit the "Bull Head" was fairly uniform in thickness and rested on an even surface of chalk, while a few yards to the west, not only did its thickness vary considerably, but it was seen to rest upon a very irregular eroded chalk surface.*

Before leaving this pit the "Drift" was seen resting on an eroded slope of Thanet Sand, and consisting of brown sandy clay with scattered pebbles, probably all local tertiary material.

Crossing King's Highway to the "Cemetery" brickfield, the

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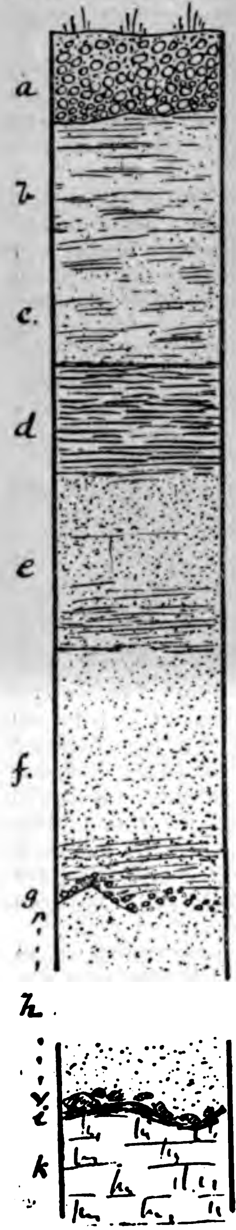
* In *Proc. Geol. Assoc.*, v, 10, p. 193, Mr. Goodchild says, "It is evident from a study of this section [Hope Cottage] and others in North Kent, that what stratigraphical break there is above the Chalk is here in the Lower London Tertiaries themselves and is not at their base, where its existence seems to have been assumed rather than to have been proved." The section seen by Mr. Goodchild is now hidden, but it was probably only a few yards from "Jenner's" pit and, apparently, exhibited the even type of junction. Without discussing the interpretation of the "Bull Head," it may be noted that isolated sections even in this small pit (c.) might lead to quite opposite conclusions as to the existence of a "stratigraphical break," so greatly does the junction vary within a few yards.

A. L. L.

fine section (D.) displaying almost the full development of the Woolwich Beds, was examined. The details are:



a. (0-5 ft.). Blackheath pebble-bed.

WOOLWICH BEDS

b. (5-7 ft.). Thinly and evenly bedded sands with thin clay partings.

c. (8 ft.). Light coloured sands with thin clay partings.

d. (6 ft.). Stiff, dark clay, with *Cyrena Ostrea*, etc.

e. (10 ft.). Fine light grey sand, very compact; in the lower part thin clay partings appear.

f. (13 ft.). Stiff greenish loam with a few widely scattered pebbles; the bottom part becomes more clayey.

g. (6 in.). Thin irregular bed of small rounded flint pebbles "splashed" into the underlying sand (=Base of Woolwich Beds).

h. (56 ft.). Fine white Thanet sand.

i. (6 in. to 1 ft.). "Bull head" bed or base of the Thanet Sand, containing green coated flints and ferruginous clayey material.

k. Chalk.

SECTION IN THE "CEMETERY" BRICKFIELD, NEAR EAST WICKHAM, APRIL, 1906.

Attention was particularly directed to the bed of very coherent light grey sand underlying the *Cyrena* clays, and to the thin beds of bright yellow, orange, and brown sands, with alternating clays, which made a very striking section in the upper part of the brickfield. "Drift" was again seen rising over eroded Thanet and Woolwich Beds almost to the Blackheath Pebble beds. A small fault (downthrow 9 inches) in the Woolwich bottom bed was clearly shown.

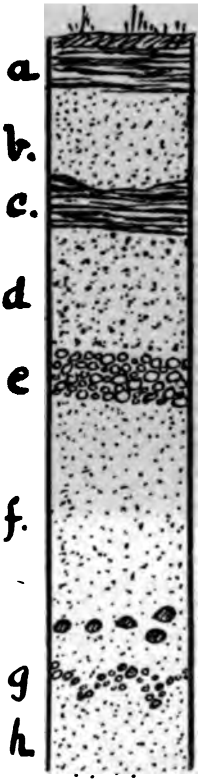
While the members were assembled in the upper pit the Directors made some remarks upon ancient and modern chalk-workings in the Wickham Valley. The brickyards, four in number, obtain chalk by shafts, 120 ft., 80 ft., 150 ft. deep; the South Metropolitan mine is entered by a sloping tunnel. Below Gregory's brickyard the aggregate length of the galleries is stated to be at least two miles. The tunnels are, as a rule, 9 ft. wide at the floor level, diminishing to 3 ft. at the roof, and 25 ft. high; but these proportions are modified according to the harder or softer nature of the chalk, the presence of joints, etc. This mine was opened about 50 years ago. The existence of ancient workings can hardly be doubted. In April, 1904, for instance, a large subsidence occurred in the "Cemetery" brickfield and part of the western "puddle-pond" sank 8 ft. Several subsidences have taken place in the adjoining brickfield, and more than once the "puddle" has suddenly disappeared through unsuspected apertures. These subsidences can only be explained by the presence of old workings, but the entrance to these remains to be discovered. A "Dene-hole," discovered in the "Cemetery" brickfield a few years ago, ran down 90 ft. through Tertiaries and Chalk, branching at the bottom in three small tunnels, but these ran out only a few yards from the shaft.

In the Chalk raised from below Gregory's brickyard fossils are fairly abundant, but *Micraster cor-anguinum* has only been found in a crushed condition. The following fossils have been obtained by the Directors and Mr. R. H. Chandler:

Micraster cor-anguinum
Holaster placenta
Echinoconus conicus
Echinocorys scutatus
Cidaris serrifera
  „ *per-ornata*
  „ *sceptrifera*
  „ *clavigera*
Zeuglopleurus Roweii
Cyphosoma, sp.
Lima hoperi
Bourgeticrinus ellipticus
Porosphæra globularis
Terebratula carnea
  „ *sub-globosa*
Rhynchonella reedensis
Parasmilia
Spondylus spinosus
Neithea quinquecostata
Inoceramus cuvieri
Axogaster
Ventriculites
Goniaster
Crania
Plicatula sigillina
Stomatopora
Spinopora dixoni
Membranipora
Diastopora

This list and a few of the chief fossils were submitted to Dr. A. Rowe, who wrote, "Your evidence on the whole is strong for *cor-anguinum* [zone]. I should have preferred to give an opinion with *Micraster* as part of the evidence; still, I have no real doubt as to the horizon."

Leaving the "Cemetery" brickfield, the party was now conducted along a great section showing Tertiaries, grooved here and there by small "drift"-filled valleys, to the south corner of Gregory's brickyard, where the relation of the "drift" to the Tertiaries was clearly shown. The Directors observed that Prof. Morris first described the Wickham valley deposits as consisting of brick-earth, sand, and gravel, 25 feet thick, and containing bones of horse, ox, and deer." Prof. Boyd Dawkins, Mr. Whitaker, and others have also noticed this "drift," but the thickness



a. Brownish sands and clays thinly bedded (1 ft.).

b. Fine light yellow sand (4 ft.).

c. Dark clays probably decalcified (9 in. to 1 ft.).

d. Light buff sand, slightly clayey (5 ft.).

e. Very compact pebble-bed of well-rounded flints (2 ft.).

WOOLWICH BEDS.

f. Loam, green when freshly exposed: thin clay partings. Many ferruginous nodules occur in this bed (12 ft.).

g. Thin irregular "splashed" pebble-bed (= base of Woolwich beds).

h. Thanet Sand.

SECTION IN THE SOUTHERN CORNER OF GREGORY'S BRICKFIELD.

(30 feet in *Memoir*) assigned to it cannot now be seen in any part of the valley. No flint implements have been found, nor are any shells recorded. The bones found in the brickearth and in the underlying gravel include elephant, horse, ox, deer, and musk sheep; those found in recent years have been presented by Mr. A. Gregory to the British Museum. The gravel which underlies the true brickearth (but not continuously) varies from a few inches to 9 feet in thickness. No good section was exposed on this occasion.

The "drift," *as seen at present*, appears to be largely a "rain wash" ("hillside drift" or "run of the hill"), and bears little resemblance to the well stratified deposits in the Crayford pits, but the main mass of the deposit, which has been almost entirely converted into bricks, may have shown more definite stratification.

The party now crossed the valley and strolled through "The Pines" to Bostal Heath, where tea was obtained at the Lodge. On the way homeward the President proposed a hearty vote of thanks to the Directors for this excursion through an interesting piece of country. The Directors having suitably responded, the members proceeded to Plumstead station, and returned to London by the 7.33 train.

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EXCURSION TO ASHTEAD AND HEADLEY.

SATURDAY, MAY 5TH, 1906.

Director: GEORGE W. YOUNG, F.G.S.

Excursion Secretary: A. H. WILLIAMS.

(*Report by* THE DIRECTOR.)

LEAVING Waterloo Station at 2.7 p.m. the members alighted at Ashtead, where they were joined by several others, the whole party numbering 38. Soon after leaving the station a halt was made while the Director pointed out the general features of the district. The Lower London Tertiaries form a narrow band dividing the Chalk mass on the south from the broad expanse of London Clay on the north.

Ashtead is but one of a remarkable line of villages on the road running from Croydon to Guildford, all of which are situated on this outcrop. No doubt the early settlers were influenced in their selection of a site, quite unconsciously, by the geological conditions. Here the London Clay would provide the woodlands, and the Chalk Downs the grazing grounds for flocks, while the variable beds between would yield the all-important good water supply.

Without entering into the whole question of the origin of parish boundaries, their outlines in this district are corroborative of this idea, and suggest that they have come down from very early times. They form long strips of land lying across the road connecting the villages so that each parish gets some of each kind of soil. This is especially noticeable west of Leatherhead.

After passing through Ashtead Park, Bishop's Chalk Pit (No. 58),* at the corner of Headley Lane, was reached. The main object of the excursion was to demonstrate the presence of the *Marsupites*-zone in this part of Surrey, and the Director explained that although at the time he read his paper before the Association he had not actually found *Marsupites* in this pit, he strongly suspected its presence owing to the proximity of the pit to the Tertiary border, and subsequently he did find it. The 300 ft. contour line is about half-way up the pit face. The main face, about 45 ft. high, is based in the zone of *Micraster cor-anguinum*. Fossils were not very numerous, but it had yielded the following: *Micraster cor-anguinum* (and var. *latior*), *Echinocorys vulgaris* (dome shaped), *Echinoconus conicus* (tumid form), *Rhynchonella plicatilis*, *R. reedensis*, *Inoceramus* sp., *Actinocamax* (? *verus*), *Porosphæra globularis*, *P. patelliformis*, and several *Polyzoa*. The beds dip north at about 2 to 3 degrees, and on the north-eastern flank the *Marsupites*-zone is displayed, with *Uintacrinus* below and *Marsupites* above. The chalk is very white and soft, but rather badly weathered, so that the actual junctions cannot be made out. This part had afforded the following fossils: *Marsupites*, *Uintacrinus*, *Bourgueticrinus* (nipple-head) *Echinocorys vulgaris* (sub-pyramidal var.) *Cidaris sceptrifera*, *Inoceramus*, *Ostræa*, *Stomatopora granulata*, and *Hydractinia*. On this occasion a fair collection was made. After a short search all the zone-name fossils, *M. cor-anguinum*, *Uintacrinus*, and *Marsupites* were found *in situ*.

A move was next made along Headley Lane, passing a large shallow pit (No. 59), where the Director had found *Uintacrinus*.

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* The numbers in brackets refer to the list given in "The Chalk Area of N.E. Surrey," G. W. Young, *Proc. Geol. Assoc.*, vol. xix, p. 188.

For a short distance the road runs along the Ermyn Street, and affords a fine view of Epsom Downs and racecourse. Soon after passing Headley Court, Clay Lane pit (No. 189) was reached. This is an interesting exposure close under the Tertiary beds of the Headley outlier, and shows about 30 ft. of massively bedded chalk, all belonging to the *Marsupites*-zone. It lies on the 500 ft. contour line, and is just two miles south of Bishop's Pit. This gives a rise of 100 ft. per mile, equal to a general dip of 1 degree, but as the dip in Bishop's Pit is more than double that there is probably a local syncline here, which would also account for the preservation of the Tertiary beds. The chalk is white and soft, but scattered flints occur in greater numbers than is usual in this zone. Only a short time could be allowed for collecting, but it sufficed for finding several plates of *Marsupites*. A full list of fossils is given in the paper already alluded to.

One-third of a mile farther on is the well-known roadside section at Oyster Hill, where the Woolwich and Reading beds contain an abundance of *Ostræa bellovacina*, but time did not permit of more than a passing glance. Tea was taken at the Clermont Inn, Tot Hill, and at its conclusion Mr. Monckton gave a short but interesting description of the Tertiary beds in this neighbourhood, after which the shortest route was taken to Leatherhead, whence the party returned to town by the 8.7 p.m. train.

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EXCURSION TO BOXFORD AND WINTERBOURNE (BERKS).

SATURDAY, MAY 12TH, 1906.

Directors: H. J. OSBORNE WHITE and LL. TREACHER.

Excursion Secretary: G. E. DIBLEY.

(*Report by* H. J. OSBORNE WHITE.)

ON arriving at Newbury, a little before 11 a.m., a party of nineteen walked through the town to the parish church, where Mr. Frank Comyns gave them an outline of the history of the building, and drew their attention to the more interesting features of the interior, including the memorial brasses to "Jack of Newbury" and his wife. From the top of the tower—reached by a narrow and gloomy newel-stair—a pleasant view over the irregular red roofs of the town and the wooded Vale of the Kennet was obtained. Here Mr. Comyns indicated the sites of those two indecisive battles of the Civil War which have been so often described by Mr. Walter Money.

The party then returned to the station and resumed their journey to Boxford, where they were joined by several other members and friends of the Association who had travelled by motor-car and bicycle.

Crossing the Lambourn, the party walked eastward along the Winterbourne Road to a small pit, in the *Uintacrinus*-chalk, on the northern slope of Hour Hill. It was explained that the Chalk there exposed formed part of an outlier of certain relatively high beds of the formation, which were well developed to the south of the River Kennet, and had once, doubtless, a wide range in the area to the north of that stream, but had been almost entirely removed from the tract occupied by the Berkshire Downs before the deposition of the oldest local Eocene sediments.

The outlier in question consisted of ordinary, and of more or less distinctly phosphatic, chalks belonging to the zones of *Marsupites* and *Actinocamax quadratus*, exposures of which, and of some abnormal beds of *Micraster cor-anguinum*-age to be seen near Boxford, were described by the Directors in a paper recently read before the Geological Society. The chalk in the pit being poorly fossiliferous, and in a carious condition, some difficulty had been experienced in determining its age. Remains of the name-fossil, *Kingena lima*, and a few other forms, however, had been found; and it was probable that the greater part, if not the whole, of the *Marsupites*-band was present in higher portions of Hour Hill, beneath the thin capping of Reading Beds and Plateau Gravel.

The members then examined the section, and succeeded in finding one of the larger free brachial ossicles of *Uintacrinus*, an Asteroid ossicle, and a few chips of oyster-shell.

The next stop was made at Iremonger's Cottages, where the outcrop of a very hard chalk, containing angular green concretions and hollow casts of sponge spicules, is indicated in a belt of rubbly soil near the boundary of the Reading Beds. The Directors confessed that they were doubtful as to the horizon of this chalk. Hard bands of similar appearance occurred at the bottom of the *Act. quadratus*-zone, and in the upper part of the *M. cor-anguinum*-zone in the neighbourhood; and while the position of this rock-band with reference to the base of the Reading Beds was the same as that of a *quadratus* rock-band a few hundred yards to the north-east, the character of the microscopic organic remains in the associated softer chalk had suggested that the beds outcropping here belonged to the lower zone. Mr. A. C. Young, however, immediately threw a light on the matter by discovering, in one of the surface-blocks of hard chalk, a fairly well-preserved and distinctly-granulated guard of *Actinocamax granulatus*—a fossil which sometimes abounds in the limestone at the base of the *quadratus*-zone in other parts of the outlier, but becomes scarce and disappears a few feet below it.

Continuing their walk eastward, the party soon reached the road-side pit opened in the thick spread of Plateau Gravel which forms the even summit of Basford Hill (465 ft. O.D.). The sides of this large excavation present good sections, 8 to 10 ft. deep, of well-stratified and cross-bedded gravel, consisting of pebbly and subangular flints, worn pieces of sarsen, small quartz pebbles, and bits of ironstone. Mr. White said, among other things, that he believed the gravel to be a fluviatile deposit of early Pleistocene age, and the work of considerable streams flowing from the Berkshire Downs country, to the north and north-west. It appeared to belong to the same drift-stage as the more extensive deposits of Greenham and Silchester Commons, on the farther side of the Kennet Valley. The flint pebbles which bulked so largely in this deposit were doubtless derived from Eocene strata—possibly of Lower Bagshot age—formerly existing in the vicinity. A worked flint, of a common Eolithic pattern,* had been obtained from the face of the pit by the speaker.

While most of the members were lunching in the shade of the bushes in the older part of the pit, Mr. P. A. B. Martin searched the gravel for implements, and succeeded in finding three or four flints which, he thought, showed clear signs of human workmanship.

In Winterbourne Wood, at a spot about one-third of a mile to the east of the above pit, a small patch of gravel, near the level of that on Basford Hill, forms a sort of shelf on the southern slope of the Borough Hill ridge. The drift, which is exposed to a depth of 6 or 7 ft. in some diggings among the fir-trees near the keeper's cottage, is distinctly stratified and very pebbly. Here Mr. Martin obtained, from undisturbed gravel, a worn flint nodule, one end of which had been subjected to regular, parallel chipping. Mr. Treacher (who is somewhat exacting in these matters) was disposed to accept the flaking as artificial. The deposit will probably repay a closer inspection.

Near the eastern edge of Winterbourne Wood, and on the north side of the road, a section of red-brown, laminated, ferruginous sand and sandstone, belonging to the Reading Beds,

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* An implement of the type referred to is figured by Mr. T. Russell Larkby in his account of an "Excursion to Chelsfield and Well Hill," *Proc. Geol. Assoc.*, vol. xix (1905), part 5, p. 241, Fig. 9, No. E 287.

overlain by a thick wash of flint-pebbles and bits of sarsen, was seen. Attention was directed to a little lens of very coarse quartz-grit which occurs in the sands at the north-eastern corner of the pit. This grit, Mr. White remarked, was much like that which formed the matrix of the Lower Eocene gravels recently observed in South Bucks.* It was not unlikely that the small quartz-pebbles present in the drifts of the Kennet Basin had been derived largely from the Reading Beds.

Leaving the road at Winterbourne Church, the party walked across the fields (permission to do so having been kindly granted by Mr. G. Baylis, of Wyfield Manor) to an unpromising-looking excavation for chalk, near Lower Farm. This showed about 12 feet of flintless, white to greyish, phosphatic chalk, with numerous brown concretions and remains of *Ostrea* and *Inoceramus*, traversed by two thin courses of hard, nodular limestone, dipping gently to the south-west. Having listened to a short account of the results of the Directors' examination of the section, and to the reasons for believing that the higher of two hard bands marked the junction of the zones of *Marsupites* and *Act. quadratus*, the members spread out along the face of the working in search of zonal evidences.

Owing to the circumstance that very few of the party were equipped with hammers of the weight and shape needed for the effective working of this tough chalk, the yield of fossils, other than oysters, was rather slow. However, before the time for leaving the pit had arrived many of the Directors' statements had been verified; the fossils obtained including a plate of *Marsupites* and teeth of *Corax* from the lower beds; sponge-casts from the hard bands; and one perfect and some fragmentary tests of depressed forms of *Echinocorys scutatus*, an *Offaster pillula*, and several damaged guards of *Act. granulatus*, from the upper beds. A very small example of *Act. granulatus*, at first mistaken for *Act. verus*, was found by the President.

The party then retraced their steps along the Winterbourne-Boxford road as far as Mud Hall (or Hole) Cottages, where they struck into the bridle path leading to Wyfield Farm. At a good view-point near the foot of Borough Hill, Mr. Comyns recited what little was known concerning the supposed "camp" on the summit of that mound-like elevation, and contrasted its features with those of the larger and better-defined earthworks of Bussock and Grimsbury to the east, and of Walbury to the south-west. One of the Directors followed with a description of the curious behaviour of the Chalk-zone outcrops on the adjoining slopes, illustrating his remarks with a large-scale map and sections.

On the way down to Boxford an overgrown pit in slightly phosphatic chalk, and a belt of rubbly ground where *Act.*

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* *Vide infra*, p. 370.

granulatus may easily be found after rain, were noticed in passing.

The last section to be visited was in an old roadside quarry north of Boxford School. This shows between 30 and 40 ft. of *M. cor-anguinum*-chalk, presenting some unusual features. It was pointed out that the ordinary flinty chalk, with many remains of *Cidaris*, at the base of the section, passes up into a hard, yellow limestone with green concretions and irregular borings; the latter being overlain by a thin seam of grey marl, succeeded by coarse-grained white chalk with few flints, and yellowish, glauconitic, hard and soft chalks, in which phosphatised micro-organisms are common, and flints very scarce. In these last beds, which are not easily got at, Mr. Treacher had found a valve of the elegant and, in this country, exceedingly rare, *Exogyra sigmoidea*, Reuss. The strata are inclined at an angle of about 25°, in a direction a little east of south, and to the flexing responsible for this high dip the Directors were much disposed to ascribe the preservation of the local outlier of newer Chalk-zones from early Eocene erosion.

The tea-hour being close at hand, and the energies of many of the members at a low ebb, little fossil-collecting was attempted, and a movement was soon made towards the " Bell Inn."

After tea, a cordial vote of thanks—proposed by the President and seconded by Mr. Dibley—was awarded Mr. Comyns and the Directors. The recipients having briefly replied, the party broke up; those who were returning by rail employing the minutes that remained before the departure of their train in gathering marsh-marigolds by the Lambourn, or in purchasing postcard-views of places more or less remote from the scene of the excursion.

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EXCURSION TO AYOT GREEN AND HATFIELD.

SATURDAY, MAY 26TH, 1906.

Directors: HORACE W. MONCKTON, F.L.S., TREAS.G.S., AND JOHN HOPKINSON, F.L.S., F.G.S.

Excursion Secretary: ARTHUR H. WILLIAMS.

(*Report by* THE DIRECTORS.)

A PARTY of 14 members and their friends arrived at Ayot station at 3.30, and proceeded to the brickfield near the station, north of the railway. Several pits in the brickfield are now open, showing a few good sections which were examined in descending order, or from newer to older deposits, the newer being to the east, near the high road (Hatfield to Welwyn). The general succession of the strata was seen to be as follows: Boulder Clay resting on Westleton Shingle on the highest ground only (406 ft.), at the eastern end of the brickfield; London Clay, with its basement-bed, in the eastern and central pits; Reading Beds in the central and western pits. The Chalk, on which these beds rest, is not exposed, but within half a mile to the south-east its junction with the sands of the Reading Beds may be seen in a shallow road-side cutting; and also in the railway-cutting about the same distance to the west.

The various pits, examined in detail, gave the following results:

In the first section, north-east end of the brickfield—

1. Boulder Clay. A little clay, with stones, not well exposed. It was very well seen on the visit of the Association in May, 1898.*

2. Gravel of flint-pebbles, quartz-pebbles, blocks of quartz, subangular flints, etc. This gravel has been referred by Prestwich to the Westleton Shingle.

In the second section, a little south of the first—

2. Gravel as above.

3. London Clay. Tolerably stiff clay of a brown colour, and partly laminated; only about 6ft. seen, but 14 ft. said to have been exposed.

4. Basement-bed of the London Clay. Rather sandy brown clay, with a layer of black flint-pebbles at the bottom.

In the third section, a little west of the second—

4. The above-mentioned layer of pebbles close to the top of the section.

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* See *Geol. Mag.*, dec. 4, vol. vi, p. 60.

5. Reading Beds. Brown, yellow, and orange-coloured sand, much current-bedded in places, with a little iron sandstone in irregular layers. Near the top, in one place, about a foot of pale grey clay, and a few irregular layers of clay here and there.

In the fourth section, western end of the brickfield—

5. Sands of the Reading Beds as above, with some much lighter in colour, in places nearly white. Two thin layers of flint-pebbles about six feet apart in the sands.

A search for fossils in the basement bed of the London Clay was unsuccessful, but Mr. Hopkinson stated that he had found teeth of several species of shark in the bottom layer of sand and pebbles, and had placed them in the County Museum at St. Albans.[*] The bottom bed of the Reading Series is not exposed; lower beds have, however, been worked, and in them a workman stated that he had found oyster-shells; nor is the Chalk exposed, but it cannot be at any great depth below the floor of the present workings, and the uneven bedding which was noticed in the Reading Beds, although partly due to current-bedding, is largely caused by irregular underground dissolution of the Chalk. This was most noticeable in the western pit.

Mr. Monckton gave a short account of the geological history of the district. With reference to the gravel on this and the neighbouring high ground, which Prestwich described as Westleton Shingle, he said that he agreed with him in thinking it to be distinct from the Glacial Gravel, and he thought that considerable earth-movement had taken place since its deposition, the preservation of this patch, and also of the patches on the neighbouring Eocene outliers, being probably due to the fact that the outliers lay on the line of a slight synclinal flexure. He doubted whether the gravel was marine, and thought it possible, as he said at Dawley,[†] that it might be the earliest gravel of the River Thames.

Mr. Hopkinson added a few words, stating that this outlier was one of several which extended in an almost straight line from beyond High Wycombe, on the south-west, to Albury, near Bishop's Stortford, on the north-east; parallel with the line of outcrop of the Reading Beds, with a few smaller and more distant outliers, and with inliers of these beds within the main mass of the London Clay, as at Pinner and Northaw; his inference being that the underlying Chalk had undergone a succession of slight folds in parallel lines in this direction. He estimated the thickness of the Reading Beds shown in these

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[*] Since this was written Mr. E. T. Newton has reported the occurrence of *Odontaspis elegans*, *O. cuspidotus*, and *Lamma Vincenti*, and also of a Teleostean, *Phyllodus toliapicus*, specimens of which he obtained from a workman.

[†] *Proc. Geol. Assoc.*, vol. xviii, p. 412.

sections as 16 ft., but their total thickness was probably from 25 to 30 ft. The outlier, he said, extended from Ayot Green, which was wholly upon it, to Ayot St. Peter's Church on the north-west, and nearly to Digswell Church on the north-east, and covered an area of about two square miles.

Leaving the brickfield the party walked through Sherrards Park Wood and across the fields which at one time were the Woodhall Woods and are so marked on the original (1834) Ordnance Map, to a large gravel pit on the east side of the main line of the Great Northern Railway, near Woodhall Lodge Farm, the section in which has already been described in our PROCEEDINGS (vol. xv, p. 310). The gravel is of glacial origin, and the chief interest of the section lies in the occurrence of two beds of Boulder Clay, one in a thick bed of gravel, and the other at the surface of the ground, showing that whatever may have been the manner in which the Boulder Clay and gravel were deposited, they are very closely connected with one another. This large excavation is now being filled in with rubbish.

The party then walked to Hatfield, and on the way, just south of the River Lea, a disused brickfield was pointed out, from which Prestwich drew his section across the valley of the Lea to Ayot Green,* but there was not time to visit it.

At Hatfield, tea was provided at the Salisbury Arms, after which, on the proposal of the President, a vote of thanks was accorded to the Directors. Hatfield Park was then visited by most of the party, by the kind permission of the Marquis of Salisbury. The Park was entered by the old gate near the church and left by the new gate opposite the railway station.

Though the weather was fine in the afternoon, but gloomy, rain had been falling all the morning and the roads were too dirty for cycling, accounting for the party not being a numerous one.

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* *Quart. Journ. Geol. Soc.*, vol. xlvi, p. 136.

EXCURSION TO THE ISLE OF WIGHT, WHITSUNTIDE, 1906.

Directors : THE PRESIDENT, G. W. COLENUTT, F.G.S., and REG. W. HOOLEY, F.G.S.

Excursion Secretary : G. W. YOUNG, F.G.S.

THE main party left London by the 5 p.m. train from Waterloo. Headquarters for the whole excursion were the Royal Eagle and Albany Hotels, Ryde, which were found very comfortable. Seventeen members stayed at the hotels, and several local residents joined each day.

Saturday, June 2nd.

Directors : THE PRESIDENT AND G. W. COLENUTT.

(*Report by* G. W. COLENUTT).

The members left Ryde by the 8.22 train for Yarmouth for the purpose of examining the cliff sections at Bouldnor, Hamstead, and Thorness Bay. After leaving Yarmouth station the party proceeded to Yarmouth Common, where Mr. Colenutt called the attention of the members to the recent erosion of the coast-line, which has greatly altered since the Association visited the locality in 1895. A sea wall has lately been erected here to preserve the highway and the common.

Diagrams were furnished by Mr. Colenutt, and these greatly aided the members in following the details of the coast sections. Proceeding along the high road for a short distance, the members descended to the shore at Bouldnor, and attention was here called to the fact that the basement bed of the Hamstead series (the Black Band), was now obscured at Yarmouth, but from here to nearly as far as Newtown River, the Hamstead Beds could be examined in the foreshore. The party walked eastward along the shore, and many fossils characteristic of the Hamstead marls and clays were found. The richly fossiliferous clays of the White Band were well exposed, and some time was spent in examining these deposits.

Below Hamstead Cliff attention was directed to the extensive "mud-glacier" which in winter time is always gradually moving down towards the sea, and exposes the upper part of the Hamstead series. Time did not permit of the members ascending the cliff to examine the Marine Band at the top, but characteristic fossils (*Voluta*, *Cerithium ornatum*, *Corbula*, etc.) were found in abundance on the weathered surface of the talus. Continuing their walk along the shore the members spent some time in further examining the sections of marl in the lower cliffs, and nearer Newtown River the Black Band was found to be well exposed below the shingle of the beach. The beds here rise up somewhat quickly, and the Bembridge Marls were well in evidence along the shore, being succeeded by the two bands of Bembridge Limestone which stretch out to sea and form Hamstead Ledge.

The Osborne Beds are masked by the recent accumulation of sand and shingle which is known as "Hamstead Duvver," and here the members halted for lunch.

After lunch the walk was continued to the eastern end of the "duvver," where a boat was in readiness and the party was ferried across the entrance of the Newtown River.

The cliffs in Thorness Bay then formed the subject of investigation. Near the entrance of the river several pieces of bones of *Bos primigenius* from the alluvium of the river were found on the beach, and a neolithic implement was also discovered. The upper part of the Osborne series only is seen in the cliffs here, and the brilliantly coloured clays yield no fossils. The strata gradually dip in an easterly direction, and the Bembridge Limestone soon descends to the sea level and forms Saltmead Ledge. The upper band of Limestone is here of a very soft and earthy nature, and this is the only locality in the Island where the perfect shells of the Limneæ are preserved; at all other places the fossils are seen in the form of casts only. Excellent specimens of these characteristic fossils were collected, as the Limestone was well exposed.

The Bembridge Marls of Thorness Bay were thoroughly worked, and plenty of fossils were collected in the cliff and shore sections. Time did not permit of any work being done in the cliffs on the eastern side of the bay, and the members walked to Great Thorness Farm, where tea was obtained.

The party then drove in brakes to Newport, calling on the way at Gunville Brickyard, where one pit showed a good section of Bracklesham Clays in a vertical position, with a peculiar drag over of the upper part of the pit, giving an appearance of a reversed dip, probably due to the steep slope of the hill. In another pit was seen the upper part of the Osborne Clays and the lower part of the Bembridge Limestone.

The return journey from Newport was made by the 7.45 train, after an interesting and enjoyable day. The weather, at times threatening, fortunately remained fine.

The following day Mr. Colenutt led a small party to King's Quay to examine the Osborne Beds which are there fossiliferous, passing *en route*, Binstead, where the Bembridge Limestone was formerly quarried for building stone, and the picturesque ruins of Quarr Abbey. Wootton Creek was crossed by ferry, and then on the shore at King's Quay a thin band in the Osborne clay was found to yield the small fish, *Clupea vectensis*, but owing to a temporary accumulation of shingle only a small portion of the fossiliferous band could be examined. In the evening Mr. Colenutt invited the party to inspect his collection, which proved of great interest, as all the strata in the Island were represented, especially those of the Tertiary formations.

Whit-Monday, June 4th.

Director: REG. W. HOOLEY, F.G.S.

(*Report by* THE DIRECTOR.)

The members took the field for this excursion in glorious weather. An early start from Ryde in the morning to Newport Station was followed by a long drive to Shepherd's Chine. Alighting at the spot where the Military Road crosses the chine the *Perna* Bed, near the base of the Lower Greensand, was pointed out. Forming Atherfield Point it rises at a low angle and outcrops at the top of the cliff near "Tie Pits," and is exposed in this chine on its curve along the northern flank of the Brighstone anticline, past the village of that name, Mottistone and Brook, to Compton Bay, where, as at Atherfield, it passes out to sea.

At the latter place its position may be followed by the eye for some distance across the bay, for at particular times the flow of the tide causes rougher water over it.

On the cliff near the mouth of the chine, where a good view of the cliffs and surrounding country is obtained, the Director explained the geology of the district, and the fauna and flora to be found in the section to be examined.

Attention was called to a curious small anticline on the eastern flank of the chine, which also appears on the west side.

Three prominent seams occur, each about two inches thick. The two lowest are *Cyrena* limestone, and the uppermost a band of ironstone. Each are separated by about 15 feet of shales. The peculiarity is, that the upper *Cyrena* limestone is bent into an anticline, whilst the band of ironstone and lower *Cyrena* limestone are unaffected. The steepest side of the anticline is to the south, contrary to the great anticlines of the south-east of England. It is not due to sagging of the beds. In time it is probably coincident with the formation of the main anticline.

The old channel of Shepherd's Brook was next examined. In Fitton's day, this brook poured its waters, after many turns and twists, into Cowleaze Chine, and thence into the sea. Now it runs straight into the sea 90 feet below its ancient bed; having cut through the many feet of Wealden Shales, and the thick bed of sandstone which forms the bottom of this chine.

Folks of the country-side speak of their grandfathers having and nearer Newtown River the Black Band was found to be well exposed below the shingle of the beach. The beds here rise up somewhat quickly, and the Bembridge Marls were well in evidence along the shore, being succeeded by the two bands of Bembridge Limestone which stretch out to sea and form Hamstead Ledge.

The Osborne Beds are masked by the recent accumulation of sand and shingle which is known as "Hamstead Duvver," and here the members halted for lunch.

After lunch the walk was continued to the eastern end of the "duvver," where a boat was in readiness and the party was ferried across the entrance of the Newtown River.

The cliffs in Thorness Bay then formed the subject of investigation. Near the entrance of the river several pieces of bones of *Bos primigenius* from the alluvium of the river were found on the beach, and a neolithic implement was also discovered. The upper part of the Osborne series only is seen in the cliffs here, and the brilliantly coloured clays yield no fossils. The strata gradually dip in an easterly direction, and the Bembridge Limestone soon descends to the sea level and forms Saltmead Ledge. The upper band of Limestone is here of a very soft and earthy nature, and this is the only locality in the Island where the perfect shells of the Limneæ are preserved; at all other places the fossils are seen in the form of casts only. Excellent specimens of these characteristic fossils were collected, as the Limestone was well exposed.

The Bembridge Marls of Thorness Bay were thoroughly worked, and plenty of fossils were collected in the cliff and shore sections. Time did not permit of any work being done in the cliffs on the eastern side of the bay, and the members walked to Great Thorness Farm, where tea was obtained.

The party then drove in brakes to Newport, calling on the way at Gunville Brickyard, where one pit showed a good section of Bracklesham Clays in a vertical position, with a peculiar drag over of the upper part of the pit, giving an appearance of a reversed dip, probably due to the steep slope of the hill. In another pit was seen the upper part of the Osborne Clays and the lower part of the Bembridge Limestone.

The return journey from Newport was made by the 7.45 train, after an interesting and enjoyable day. The weather, at times threatening, fortunately remained fine.

The following day Mr. Colenutt led a small party to King's Quay to examine the Osborne Beds which are there fossiliferous, passing *en route*, Binstead, where the Bembridge Limestone was formerly quarried for building stone, and the picturesque ruins of Quarr Abbey. Wootton Creek was crossed by ferry, and then on the shore at King's Quay a thin band in the Osborne clay was found to yield the small fish, *Clupea vectensis*, but owing to a temporary accumulation of shingle only a small portion of the fossiliferous band could be examined. In the evening Mr. Colenutt invited the party to inspect his collection, which proved of great interest, as all the strata in the Island were represented, especially those of the Tertiary formations.

Whit-Monday, June 4th.

Director: REG. W. HOOLEY, F.G.S.

(*Report by* THE DIRECTOR.)

The members took the field for this excursion in glorious weather. An early start from Ryde in the morning to Newport Station was followed by a long drive to Shepherd's Chine. Alighting at the spot where the Military Road crosses the chine the *Perna* Bed, near the base of the Lower Greensand, was pointed out. Forming Atherfield Point it rises at a low angle and outcrops at the top of the cliff near "Tie Pits," and is exposed in this chine on its curve along the northern flank of the Brighstone anticline, past the village of that name, Mottistone and Brook, to Compton Bay, where, as at Atherfield, it passes out to sea.

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Folks of the country-side speak of their grandfathers having told them, that, in their day, a road passed along the top of the cliff, and only a low bridge was necessary to enable the crossing over the chine to be made. Local legend also has it, that the stream was diverted because a shepherd dammed the water back from Cowleaze Chine to lessen the distance he had to walk for watering his flock, and thus an inchoate breach was made through the shales direct to the sea, instead of meandering parallel to it.

It is well to record the date of the visit of the Association, for the denudation of the strata composing the cliff has been so great in recent years that soon all traces of the old channel will be obliterated.

Walking down and up the sides of Cowleaze Chine and along the cliff to Barnes High, a precipitous descent brought them to the shore near a green coloured bed full of lignite, from which many *Dinosaurian* bones and teeth, *Goniopholis* teeth, fruits, seeds, and *Unio* are obtained, but as often happens on show occasions it gave up only two or three specimens of *Unio* to the researches of many hammers.

The two characters of the Wealden strata of Atherfield were noted. The lower group consisting of red, mottled and variegated clays, marls, and sandstones; and the upper of blue shales with thin seams of limestone and thick sandstone.

The extreme inconstancy of any given bed of the Wealden strata was well illustrated by a bed which near Cowleaze Chine is a compact sandstone and a few hundred yards westward has passed into grey shales, from which the Director procured a fine series of *Vertebræ*, and the bones of the pelvic girdle of *Iguanodon bernissartensis* in 1890. The *Hypsilophodon* Bed at the junction of the variegated strata with the blue shales could be traced, but was generally much hidden by rain-wash and talus.

Near Cowleaze Chine attention was called to a thin seam of shale underlying the sandstone that forms the bottom of this chine as the first horizon where estuarine conditions commence to be recorded.

Splenials of the Pycnodont, *Cœlodus Mantelli*, and spines of *Hybodus* are found here, and one of the latter was discovered after a brief search.

Passing the massive sandstone that rising from the beach near Shepherd's Chine forms and outcrops at Barnes High, a fern bed a few feet above was worked, and many portions of *Lonchopteris Mantelli* were secured. At "Tie Pits" a deep and long indentation in the coast line was seen extending about 150 yards and 50 yards deep, from which, in the autumn of 1904, a huge "founder" of Wealden Shales took place. A few feet of the Atherfield Clay, and the *Perna* Bed, which also fell, alone remain to be scoured away by the next "ground" sea. The "founder" did not topple over, but gradually sank, pushing its foot across the beach into the sea. The Director mentioned that he had obtained, washed out of this, many fine and valuable specimens which were cast up by the waves free of the matrix.

Specimens of Cyrena limestone were collected here, and a short way farther east, from two thin bands of ironstone, together with dwarfed individuals of *Exogyra*.

The thin band of "Beef" (calcite) showing cone in cone structure was reached near Atherfield Point, where lunch was taken. The party then began collecting fossils from the blocks of Perna rock which had fallen from the cliff, and many of the characteristic species were gathered.

The junction of the Wealden Shales and Lower Greensand was particularly well exposed, and several interesting hand specimens were obtained, amongst which was one containing *Arca* and *Panopæa* in the Lower Greensand, and *Cyrena* and *Lonchopteris Mantelli* in the Wealden Shales. In the grit bed teeth of Lepidotus and rolled sharks' teeth and pieces of bone were found. The Atherfield Clay, with its blue colour and soft unctuous nature, contrasting so greatly with the green sandy grit of the Perna Bed, was next examined, and though it yields many fossils—especially Pinna and Panopæa in the upright position they occupied in life—the watch did not allow time to find them. Towards the top of the bed the small lobster *Meyeria vectensis*, the crab *Mithracites vectensis*, and an echinus occur. The hard calcareous nodules of the Ferruginous Sands, called by Fitton the "Crackers," were investigated *in situ*, and several were broken by sledge-hammer wielded by the coxswain of the Atherfield Life Boat. It is only in the soft sandy hearts of these blocks that fossils can be obtained, although they may often be noted running through the mass; especially is this the case with *Gervillia Hoplites*, *Arca*, *Thetis*, *Trigonia*, *Natica*, *Apporhais*, and several other specimens were disinterred.

Reaching the Lower Gyphæa (Exogyra) Group of Fitton, fallen blocks of the iron-coloured beds of the base yielded· *Terebratula sella*, *Rhynchonella gibbsiani*, and other shells; but no sharks' teeth, which are sometimes common, were found. The Scaphite and Crioceras Groups were pointed out as they were passed, and specimens of both these fossils were seen *in situ*. A good specimen of Scaphites (Ancyloceras) gigas in a fallen block on the beach, Mr. C. J. Coleman, helped by the President, chiselled out in three pieces. Whale Chine, a gorge cut through the Upper Crioceras, and Walpen Sand, and Clay Beds of Fitton, by an ever running stream, was studied, also Ladder Chine, where in many seasons the surface drainage contiguous to it finds a course, or after a storm, but its flow is at all times of short duration. This chine has been excavated almost entirely by wind action, and many interesting results of this erosion were examined and several "snapshots" taken by the photographic section of the party.

The cliff was ascended through this chine, the top of which is surmounted by the chert gravel of the Old Western Yar.

The way was made by the Military Road to the Clarendon Hotel, Chale, where tea was thoroughly enjoyed after the arduous walk along the shingle beach. At 6 p.m. the party drove back to Newport, whence headquarters at Ryde were reached by train at a late hour.

Tuesday, June 5th.

Directors: THE PRESIDENT, ROBERT S. HERRIES, M.A., V.P.G.S., AND REG. W. HOOLEY, F.G.S.

(*Report by* REG. W. HOOLEY.)

In spite of the late return home the previous night the party were early astir. Ryde Station was left by the 8.22 a.m. train, and Freshwater Station reached by 9.37 a.m. The journey to Alum Bay was made on foot. On reaching Alum Bay the end of the pier was sought, for it is the only spot, without taking a boat, where a good general view of the section from the Chalk to the Bembridge Limestone is obtained. Here the Directors explained the geology and the points to be particularly studied that day. It was decided to examine the strata in ascending order; a move was therefore made along the beach to the Chalk. The dip of the Chalk here is about 80 degrees to the north. It is the Upper Chalk with flints. As is the case in other parts of the Island where the Chalk is greatly inclined the flints, some of them of great size, may be observed completely shattered, but held together by the mass of Chalk surrounding them, so that on freeing them they fall to pieces. Some are in their centres almost pulverised. This fracturing has been caused by the force that upheaved the whole. Mr. Geo. W. Young here made some interesting remarks in regard to the Chalk, particularly pointing out that the whole of the cliff face from this spot to the Needles was in the zone of *Belemnitella mucronata*, and largely coincided with the dip in the beds.

The face of the Chalk upon which the Woolwich and Reading Beds had been lying was splendidly exposed. Many potholes were to be seen filled with sand, clay, and rolled pebbles, and near the top of the cliff a fresh denuded surface showed rounded bosses of Chalk, worn thus by the play of water around them, as is to be seen on any shore between high and low water mark, or, for instance, on the hard "platina" of the Wealden Beds in Brighstone or Brook Bay. At the base of the Woolwich and Reading Beds a layer of rolled flint pebbles occurs. No green-coated flints are found here. Mr. Whitaker said that this was different to any other junction of these strata he had examined. The Woolwich and Reading and London Clay Beds were then investigated. No fossils in the former, but in the latter

Pinna affinis, *Petunculus brevirostris*, and others were found. In the upper part of the cliff the reversed dip of the beds was noticed; in the lower portion they are vertical.

The pipeclay in the Lower Bagshot Beds, which has yielded numerous perfect leaves of tropical plants, and which was known to Mantell, was described by the Directors. Although for many years it has been badly exposed, and poor specimens obtained, it is now prominent, standing well out from the sandy beds on either side of it. After splitting asunder several lumps, a fine leaf of *Ficus* and also portions of *Laurus*, *Quercus* and others were discovered. Passing the Bournemouth Freshwater Series of Gardner, the Bracklesham Beds were reached. The coal or lignite seams with the under-clay in which the vegetation grew afforded much interest. Several bands from one to two feet in thickness were examined. Another bed splendidly exposed was the pebble conglomerate in the Bracklesham Beds, through the denudation of the white and yellow sands underlying them in time. Some of the pebbles are nearly a foot in length and all lie with their longer axes parallel with the lines of bedding. Running vertically up the cliff they cannot fail to attract the attention of even the least curious, for it is apparent nothing known to man could thus have deposited them. A recent fall of the Barton Clay gave a good opportunity for the collection of fossils. Passing to the Headon Hill Sands, their junction with the Lower Headon Series was finely displayed. At the north corner of Headon Hill the Headon beds were worked for fossils and many characteristic specimens obtained. Time did not permit the climb over the small cliff made by the thick bed of Limestone near the top of the Upper Headon, to examine the Osborne Beds and Bembridge Limestone. An extra half-hour had already been absorbed, and this was regained by deciding to partake of lunch in the brakes *en route* to Brook, which place was reached about 3 p.m.

Immediately proceeding to Hanover Point, the fossil "Pine-raft" was examined.

The tide was very favourable for this, although many persons have taken away blocks for various purposes, and, in spite of the fact that a ship recently ran ashore on it, much yet remains. At certain times, when the beach is removed by the sea, logs are to be seen sticking out of the foot of the cliff at the Point; more therefore remains to be uncovered. The trunks; and portions are lying scattered, and coated with sea wrack, between high and low water mark.

One tree measures 24 feet with a diameter of three feet, and is the longest to be found. Very curious arborescent markings were noted in the section of some of the trees. Teeth and scales of *Lepidotus mantelli* were found in the sandstone in which the stems of the trees are embedded. The Director (Mr. Hooley had now taken sole charge) gave a brief account of the Pine-raft, and of the section from Brook Chine to Afton Down, pointing out the deep red marls the lowest beds exposed at the surface in the Isle of Wight, and the small chine where Hulke obtained

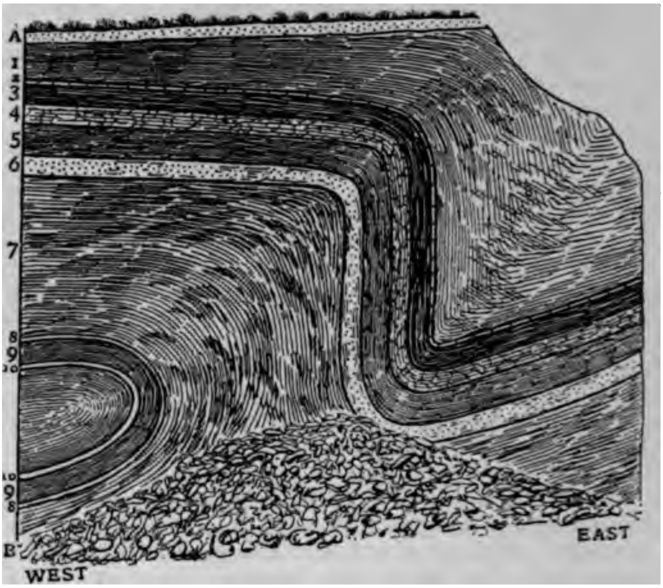

FIG. 1.—SECTION ABOUT 150 YARDS WEST OF SMALL CHINE, TO THE WEST OF COMPTON GRANGE CHINE, COMPTON BAY, ISLE OF WIGHT.

		Thickness. ft.	in.
1.	Grey Shales	2	0
2.	Cyrena Limestone	0	2
3.	Shales	1	3
4.	Iron Clay Stone	1	0
5.	Grey Shale	1	9
6.	Sandy Shale	1	2
7.	Blue Shale	8	6
8.	Sandstone	0	4
9.	Shale	1	2
10.	Iron Clay Stone	0	6
11.	Shale . 5 ft. from bed 10 to 10 = 2 ft. 6 in. stratum folded double.		
A.	Soil		
B.	Talus		

Variegated marls on the west faulted against this section.

REG. W. HOOLEY.

many fine reptilian remains. He referred to the repetition of both groups of Wealden strata, the variegated and the shales, giving the evidence for and against a fault being a cause, and stating that the cliff at the probable position was now well cleared of talus, so that the second series of variegated beds could be shown to be faulted against the shales. Proceeding along Compton Bay the section of alluvium near Shippard's or Compton Grange Chine containing hazel nuts, elytra of beetles, and wood was visited. Nuts were found underlying 6 ft. of brick-earth, and again below 2 ft. of gravel. This alluvium is newer than that covering the contiguous cliffs.

Near here, intercalated in the older gravel above mottled Wealden Beds, a mass of blue clay was noted, probably derived from the denudation of Wealden Shales. About 150 yards west of a small chine, also west of Compton Grange Chine, a clean section showed contorted Wealden Shales as in Fig. 1. Beds 11, 10, 9, and 8 curve in a semicircle. The remaining beds do not take this curve, but bend at right angles, and thus are vertical for a few feet, then again turning they begin to take the true dip.

Through slip the portion of the cliff, in which this section occurs, shows a section at right angles that is bearing inland. A few yards along this variegated marls are lying directly against these contorted shales. The line of junction was visible on removing with a pick a few inches of wash that hid it.

The trend of the fault is apparently E.N.E. The presence of a fault has been suggested by different observers, but some have thought otherwise, for the reason, amongst others, that the upper series of shales, being only about half the thickness of the lower, it seemed hardly possible that they could have thinned out so considerably in so short a distance as the presence of this fault proves them to do, for the upper series of shales and marls must be correlated with the lower here. This agrees with the one group of shales and variegated strata at Atherfield and Sandown. Leaving here the Atherfield clay was examined at the top of the cliff, and the Perna Bed, with Gryphæa (Exogyra) sinuata in displaced portions of the cliff. This clay is the cause of the rough and tumble state of the cliff here.

It was noted how great is the contrast between the strata of the Lower Greensand in this section and that of the Atherfield. Time would not permit more than a passing notice of the remaining strata to the Chalk.

The ascent of the cliff was made up the talus formed by the Gault Clay and Freshwater Bay was reached. Tea was provided at Stark's Hotel.

The party took the 7.5 p.m. train back to Ryde.

Wednesday, June 6th.

Directors: THE PRESIDENT AND G. W. COLENUTT.

(*Report by* G. W. COLENUTT.)

The last day of the excursion was devoted to the examination of the well-known sections of Chalk, Eocene, and Oligocene

Beds in Whitecliff Bay, and the party left Ryde by the 9.19 train for Brading.

Proceeding through Centurions copse, the way led across fields to the edge of the cliff, about the middle of Whitecliff Bay, and here the party descended to the beach. Attention was first directed to the Culver Cliff, where the uppermost zone of the Chalk can be seen, but the tide was too high to permit the members getting round the end of the cliff.

The Reading Beds yield few fossils here, and the London clay also is not rich in organic remains. The Bagshot, Bracklesham, and Barton Beds were in turn examined, and from them the characteristic fossils were collected. The lower, middle, and upper Headon Beds were seen in the cliff and yielded their usual organic remains. The Osborne Beds and the Bembridge Limestone also received ample attention, and a hasty examination was made of the Marine Band crowded with *Ostrea vectensis* which directly overlies the Limestone.

The party walked back to Brading, and after tea at the Wheatsheaf Inn returned to Ryde by the 4.48 train *en route* for the mainland.

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EXCURSION TO STAMFORD, COLLYWESTON, AND KETTON.

SATURDAY, JUNE 16TH, 1906.

Director: BEEBY THOMPSON, F.C.S., F.G.S.

Excursion Secretary: W. P. D. STEBBING.

(*Report by* THE DIRECTOR.)

A PARTY of seven left London by the 8.45 a.m. train from King's Cross (G. N. R.), and reached Stamford a little after 11 a.m., where they were met by the Director. After a short delay, they drove along the road on the southern side of the Welland valley, towards Easton and Collyweston.

Stamford town is mostly on the Lincolnshire Oolite formation, but portions are on the Northampton Sand, and the bed of the river reaches to the Upper Lias Clay. After a rather steep ascent from Stamford, and when nearing Wothorpe with its ruins of an old Burghley mansion, attention was called to exposures of the ferruginous beds of the Northampton Sand by the roadside. These beds are near the base of the Northampton Sand, and are probably about 100 ft. higher than the same beds on the same side of the Welland Valley, at Stamford. This difference of level is due to a "fault" between Wothorpe and Stamford, running approximately east and west, which "fault" has been traced for several miles in an easterly direction from the Welland valley. (See Geological Survey Map, Sheet No. 64).

From this point, Wothorpe, and the rapidly rising ground between here and Easton-on-the-Hill, good views of Stamford and the Welland valley were obtained.

COLLYWESTON SLATES.—The Collyweston slate quarries commence soon after passing Easton, and extend for about a mile on each side of the road, right up to the village of Collyweston.

One sees numerous, comparatively small, walled-off patches of ground and little else from the road, as the actual quarry is mostly underground, and useless material is stacked underground to keep up the roof of previously excavated portions.

One quarry only was particularly examined, that on the east side of the road nearest to Collyweston. Before proceeding to inspect the workings, the Director gave a description of the geological position of the Collyweston Slates and the method of working them about as follows:—The Collyweston Slate is a fine-grained, calcareo-arenaceous rock, occurring at or near the base of the Lincolnshire Oolite formation, the Lincolnshire Oolite itself being a strictly local limestone deposit occurring between the Lower Estuarine beds of the Inferior Oolite, and the Upper Estuarine beds of the Great Oolite. The Collyweston quarries have been worked in a similar manner to the present method of working for upwards of 400 years, that is to say by "foxing"—working underground in "foxholes"—though there have been and are now, some open workings. The quarrying is done in the winter, up to January, both to avoid trouble with water in the workings, and to take advantage of the frosts and thaws of the early part of the year to split the stone; the dressing is done in the summer in the open, with a mere wind-screen of wattled straw.

There is only one bed of stone yielding slates, but it varies in thickness from 6 in. to, in rare cases, 3 ft., or its place may be entirely occupied by sand. The blocks of stone on being brought to the surface are spread out on the ground to be frosted, and they must not be allowed to get dry internally before the frost acts on them, and so, if necessary, they are regularly watered up to about the end of March. The stones are split by the freezing of water along the bedding planes, and of course if there is no water left to be frozen there will be no splitting effect, besides which the evaporated water leaves behind a deposit of carbonate of lime which helps to bind the layers together. Spoilt slates are stocked and sold for road metal. The cleaving of the stones by the workmen after they have been split by frost is easy, though requiring skill. Dressing and trimming follow the splitting, and the slates are stacked in different sizes.

After securing a few fossils, including several specimens of the characteristic winged gasteropod *Pterocera Bentleyi*, most of the party, including two ladies, descended to the underground workings by means of a ladder,* and walked along the headings. The slate is undercut and overcut to facilitate extraction without injury, and the waste material piled up in the excavated area to keep up the roof.

After leaving Collyweston the party drove down the steep incline to and across the Welland Valley to Ketton, where a little time was spent in inspecting the interesting various-styled "Barnack Rag" Church.

KETTON FREESTONE.—The chief freestone quarry at Ketton now is Molesworth's, just west of the village, and this was examined under the guidance of Mr. Molesworth and his foreman. The section where most fully shown includes just a little Great Oolite limestone; below this the whole of the Upper Estuarine beds, and then the Lincolnshire Oolite limestone.

Only a few feet near the top of the Lincolnshire limestone is worked for building stone, and considering the large amount of

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* The usual entrance by an incline had been walled up "to keep out the weather," as the workmen said. The depth of the workings is from 15 to 25 ft.

overburden to be removed to get at it, it seems a wonder it can pay to get, until one examines the stone and sees what a beautifully perfect oolitic freestone it is. It is sawn easily without sand or water, but hardens considerably on exposure. It weathers well, and is found to possess great strength and durability.

The Upper Estuarine Clays here consist of two or three beds, and small faults, and various contortions due to slipping are observed. The clay is dug by steam navvies, and carted away to tips, which tips already form miniature mountains. These clays can be made into very good bricks, as indeed they are at Stamford, but owing to the absence of railway facilities it is not found to pay in competition with the huge brickworks near to Peterborough.

The top of the Lincolnshire Limestone at the Ketton quarries is more than 100 ft. below the bottom of the same formation at Collyweston, two miles away, and as the thickness of the formation itself is probably 70 ft., there is a difference of level of some 170 ft. or more; moreover, the Collyweston beds, which are the highest in position, lie in the direction in which there should be a dip down, consequently a very considerable fault is indicated. The whole neighbourhood, indeed, is very much faulted.

After leaving Molesworth's Freestone quarries, a short inspection was made of the immense area of broken ground where were the old quarries which made Ketton Freestone famous. No attempt has been made to level it down.

Re-entering the conveyance, the party then drove through Tinwell to Stamford, and visited two sections to the north of the town.

THE STAMFORD LIME WORKS.—Just to the north of Stamford, on the road to Little Casterton, is a large limestone quarry in the Lincolnshire Oolite, where the stone is dug and burnt for lime. This is the quarry which Sharp (see references) describes so fully under the name "Tinkler's Quarry." The section of 30 to 40 ft. gives a good idea of the main mass of the Lincolnshire limestone, that is to say, it is a somewhat argillaceous or marly limestone (marlstone), containing many fossils. There is reason to believe that the entire thickness here would be about 70 ft. The stone has been worked for building and interior ornamental purposes under the name of "Stamford Stone," and a particularly hard, fossiliferous, crystalline bed which will take a good polish has been used as a marble, for chimney-pieces, etc., under the name of "Stamford Marble." At the present time the stone is only quarried for lime burning, some of which lime is further ground for agricultural use.

STAMFORD BRICK WORKS.—These brickworks are situated near to but at a higher level than the lime works last described, and so form a continued upwards section with little loss. These works, which were visited by kind permission of the proprietors, Messrs. Towers and Williamson, are those described by Sharp (see References) as Torkington's brick-pit. The entire section at the present time consists of the Upper Estuarine beds, and is a just about complete one, the complete one being about 28 ft. From the clays are made fire-bricks, paving slabs, white or buff building bricks and tiles, and occasionally terra-cotta.

The clay appears to be worked in three tiers about as below:

	Approx.	
	ft.	in.
(1) Sandy layers, coarse shaly clay, and grey clay, with numerous shells, also plants and wood	9	0
(2) Variegated, dark blue, chocolate-coloured, purple, and yellow clay, with abundant carbonaceous matter ...	12	0
(3) Grey sandy clay, with exceedingly numerous fine, vertical plant marking. Red joints and streaks in the lower part	6	0
(4) Rich Ironstone, with a layer of gypsum on top	0	9

No. 2 is the best brick clay.

No. 4 is evidently a bog iron ore, as there is much wood in it, and the layer of gypsum on top points the same way. The party were able to see in one part of the quarry, in the top portion of the ironstone, part of a tree trunk about 6 ft. long and 3 ft. in circumference, mostly converted into ironstone, but here and there showing structure.

There was not time available to see the Great Oolite limestone quarries farther up the hill.

The party drove back through the town to the George Hotel, where a meat tea had been provided. A vote of thanks was accorded to the Director, and the party left for London about six o'clock.

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ON THE OCCURRENCE OF QUARTZOSE GRAVEL IN THE READING BEDS AT LANE END, BUCKS.

BY H. J. OSBORNE WHITE, F.G.S.

(Read June 8th, 1906.)

A RECENT enlargement of one of the numerous excavations for sand and clay that occur in the sides of the well-known Eocene outlier of Lane End, on the Chiltern Hills, has exposed, in the upper part of the Reading Beds, a series of coarse-textured deposits which are unlike any hitherto seen by me in that formation within the Tertiary Basin of London. The pit referred to is situated near the border of Ditchfield Common, at a point rather less than a hundred yards to the south-east of the parish church at Lane End, and close to the road leading from that village to Moor End Common and Frieth. It has been worked for many years, and sections formerly visible there were described by Mr. Whitaker in 1872,* and by me in 1899; the latter account being a very brief one embodied in a report of an excursion of the Geologists' Association.† These older sections, which were on the western side of the working and are now obscured by slips, showed the lowest beds of the London Clay (in a more or less reconstructed condition) resting upon light-coloured Reading Sands with thin beds of fine grey clay and a little ironstone. The newer exposures, which are on the eastern side, also show the Basement Bed of the London Clay, but the underlying sands are coarse and shingly, and contain lenticular bodies of current-bedded, subangular gravel of fine to medium texture.

The principal features of the section, as it appeared in January of the present year, are indicated in the accompanying sketch (Fig. 1), and the beds there numbered in descending order are described below.

		Feet.
	1. Soil and made ground, mostly of brown clay.	
LONDON CLAY.	2 (*Basement-Bed*). Evenly-stratified loamy sand with continuous seams of light, blue-grey, stiff clay, and of dull green, speckled, glauconitic sand; small concretions and laminæ of brown clay-ironstone. At the base, a slightly undulate band (6 inches thick) of glauconitic, loamy sand containing flint pebbles (some of large size), and a few small quartz-pebbles	5 to 6

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* "The Geology of the London Basin," *Mem. Geol. Survey*, vol. iv, p. 207. Republished in *The Geology of London* (1889), vol. i, p. 183.

† *Proc. Geol. Assoc.*, vol. xvi, part 5, p. 252.

		Feet.
READING BEDS.	**3.** Buff and brown sand, loamy in the upper part, with some small quartz-pebbles and seams of light grey clay. (This division is cut out by the London Clay at the northern and southern ends of the section; and its base, which is marked by a thin but persistent band of clay, curves downward in the middle of the section so as to truncate the irregular beds in the division below)	to 3
	4. (*a*) Buff and brown sand with seams of grey clay ... ... to 2 ft.	15
	(*b*) Lens of current-bedded quartz, flint, and clay-gravel ... ... to 3 ft.	
	(*c*) Fine buff sand, with small lenses of gravel, and a seam of laminated clay at the base to 2 ft. (In the southern part of the section beds (*a*), (*b*), and (*c*) appear to be represented by alternations of blue-grey clay and ferruginous sand.)	
	(*d*) Irregular bed of gravel; cemented in places,—and especially in a band, a few inches wide, at the top—by red and brown iron oxide...to 4 ft.	
	(*e*) Buff, yellow, and light brown gravelly sand; markedly current-bedded and full of small quartz-pebbles. A lens of gravel seen in one place ... ... to 5 ft.	
	5. Friable, coarse-grained sandstone, without pebbles; light brown above, and greenish yellow below...	2
	6. (*a*) Firm brown sand, with scattered small pebbles 2 ft.	2½
	(*b*) A bed or patch of wet gravel, just touched at the bottom of a temporary hole in the floor of the pit ... ... seen 6 in.	

The coarser materials of the gravels and gravelly sands are:

Quartz-pebbles: White, yellowish, and pink; translucent and opaque. These are generally incompletely rounded, and range up to 1½ in. in diameter. They form the bulk of the gravel.

Subangular flints: Mostly bleached a dull white, but commonly possessing a green tinge on the outside. Many are red within. A large proportion of the flints in this condition are fragments of tabular seams or veins; and pieces of "carious" or "cavernous" nodules are abundant. Some of the less worn flints, which have formed part of solid nodules, fall into small splinters when removed from their matrix. Size: common up to 2 in.; a few ranging up to 6 or 7 in. in diameter.

Flint nodules: Little worn. Mostly small and of globular and subcylindrical forms. Some are hollow and spongeous, and many have the dark green coating and corroded surface which characterise the nodules in the Reading "Bottom Bed." Small, club-shaped nodules, enclosing the lower portions of the stems of Coscinoporæ, are fairly common.

Flint pebbles: Black and grey, fairly common up to 1½ in. in diameter, but greatly outnumbered by subangular flints.

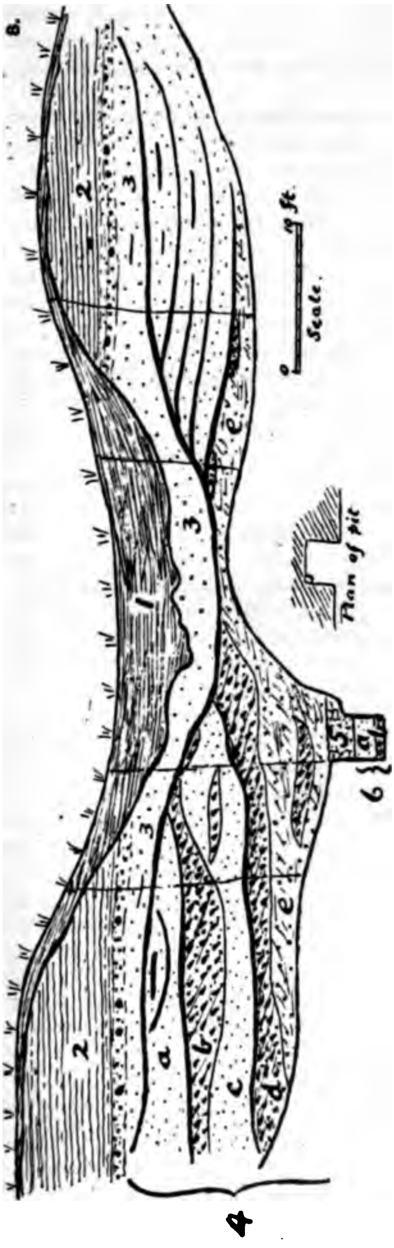

FIG. I.

Clay: In sub-angular pieces and pebbles up to 4 in. in diameter. In some places these are so closely set as to give the gravel the appearance of a breccia.

Ironstone: In flaggy pieces and in concretions, enclosing pebbles of clay and other material.

Lydite: Black, polished, imperfectly rounded pebbles of chert or other siliceous rock; often dull brown within. Mostly under $\frac{1}{2}$ in. in diameter.

Quartzite, or very compact, fine-grained sandstone, of light grey and light brown tints: in small ovate pebbles, to $\frac{5}{8}$ in. in diameter.

Sandstone: Brown, in pebbles to about $\frac{1}{2}$ in. in diameter.

Silicified Inoceramus-shell: Small pieces, abundant in places.

The interest of the above section centres in the beds and lenses of gravel and gravelly sand. Brecciate and conglomeratic beds, consisting of angular and rounded pieces of clay in a sandy matrix, are of common occurrence in the Reading series; sub-angular flints, also, have been noted in many places (though rarely in such quantities as here), but I can find no record of the occurrence of gravel abounding in pebbles of quartz and lydite in that series in any part of the London Basin.*

Recalling the confused state of some of the beds formerly visible on the western side of the excavation, I at first suspected the gravelly sands, with their uneven seams of clay, to be an elaborately deceitful sort of hill-wash or "trail," and their covering of London Clay to be one of those foundered masses so common on the flanks of the larger Eocene outliers. An examination of the section, however, revealed nothing to justify that interpretation, and much (in the way of structural detail) that was entirely opposed to it; and the small remaining doubts as to the Eocene age of the gravel-beds were soon dispelled by the discovery of similar deposits, associated with Reading Beds, in another part of the Lane End outlier.

By the Kiln near Muzwell Farm, at a spot about half-a-mile south-west of Lane End church and the section just described, there is an old and deep excavation in mottled clay, sands and loam. The beds here have been so much disturbed by the movements responsible for the trough-faulted syncline of Moor End Common, a little to the south, that their succession cannot be made out, with any certainty, in the present obscured state of the section. Coarse, gravelly, current-bedded sands, with lenses of ferruginous gravel, closely resembling those seen near the church, occur at the lower south-western end of the working, and might be inferred to pass beneath a considerable thickness of brown sand and mottled clay visible at higher levels close by; but their apparently low position in the Reading Series here is almost certainly due to a strong south-westward dip, for there are some indications of the London Clay and its pebbly base in the disturbed ground which overlies them; and the occurrence of "very coarse" sand just beneath the basement bed of that formation at this place has been noted by Mr. Whitaker.†

The composition of the gravel is, qualitatively, the same as in the last section, but the small spheroidal flint nodules and fragments of tabular flint are more numerous, and the average size of the quartz-pebbles is rather greater.

There would seem, then, to be a considerable development of coarse sediment in the upper part of the Reading Series in this neighbourhood. It may be recalled that the lower beds of the formation in the Lane End outlier contain, at Boulter End, an exceptionally large shingle-bank which, where seen in section, consists of well-rounded and closely-packed pebbles of flint.

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* Rounded and angular flints in light-coloured Reading clay and sand, with "a few small quartz pebbles," were seen by Mr. Whitaker, at Stoke Row, in Oxfordshire, *Geol. Survey Memoir*, on Sheet 13 (1862), p. 42.

† "Geology of the London Basin" (1872), p. 208, and "Geology of London" (1889), vol. i, p. 184; see also *Summary of Progress of the Geol. Survey for* 1900, p. 122.

Containing much subangular material, and lying, as they seem to do, in current-scoured hollows amid banks of finer sediment, the gravelly sands above described have a distinctly fluviatile, or estuarine, aspect. Their restriction, or apparent restriction, to an outlier situated in the outermost line of such residual masses on the northern slope of the London Basin* naturally suggests that their constituents were derived from land lying to the north, or north-west; and, having regard to the nature of the uncomformity between the Lower Eocene and Upper Cretaceous strata in this part of England, the character of some of these constituents renders it probable that such was actually the case.

The small spheroidal and subcylindrical spongeous flints, which are so abundant in these gravels, are especially characteristic of the *Micraster cor-testudinarium*-chalk of the Chilterns and Berkshire Downs, and bits of *Inoceramus*-shell, of the kind found here, are particularly plentiful at or about the same horizon. Near Lane End the Eocene rocks rest on the newer, *M. cor-anguinum*-beds, which have a local thickness of at least 130 ft., but the general tendency shown by the Reading Beds to overstep the Chalk towards the north or north-west leads to the inference that lower sub-divisions of the latter formation came within reach of early Eocene erosion in the Midland area, north-west of the Chiltern Hills.

The pebbles of dark chert or lydite, which appear to be identical with those of the Portland Beds of the Vale of Aylesbury, also are suggestive of the northern derivation of the Lane End gravel. These little black stones, and pieces of quartz, are almost the only materials occurring in the Jurassic and Lower Cretaceous rocks of the Southern Midlands which would be likely to survive transportation, and long exposure to percolating water in a sand, in the condition of pebbles.

If these Reading gravels are the waste of a land which lay somewhere to the north, similar or even coarser deposits are likely to have occurred, and with increasing frequency, in that direction; and it may well be that the Lane End beds, which are in such marked contrast with the normal type of Reading sediment in the London Basin, present to us a facies of the formation which was a common one on the Chalk platform once extending beyond the present escarpment of the Chiltern Hills.

Now, having regard to the general south-eastward inclination and drainage of the rocks on this side of the London Basin, it can hardly be doubted that the superficial deposits on the Chilterns include some of the débris of the Chalk and newer strata which once overspread the area occupied by the Vale

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* Since submitting this paper to the Secretary (in February, 1906) I have recognised remains of similar deposits in some blocks of very coarse ironstone-conglomerate occurring in the Clay-with-Flints at Queen Wood, and in loose drift associated with disturbed Reading loams at Russell's Water, in Oxfordshire. These places are five to six miles east of the Lane End outlier, and high up on the dip slope.

of Aylesbury; and it is, therefore, of especial interest in the present connection to note the prevalence of quartzose drift-gravel upon those hills. The gravel I refer to is the well-known variety of the Geological Survey's "Pebble Gravel," which the late Sir Joseph Prestwich regarded as the inland extension of the Pleistocene marine shingle of Westleton, near the coast of Suffolk.

The "Westleton" hypothesis has not (to say the least) met with general acceptance; nor have the other suggestions relative to the age and origin of this upland drift, which have been brought forward since the publication of Prestwich's views in 1890, called forth many expressions of approval. One of the chief difficulties—if not the chief difficulty—hitherto, has been to account for the abundant quartz-pebbles. Marine currents and rivers setting out from divers distant regions of quartzose rocks have been invoked, but the immediate source of this material has remained uncertain. Now, however, that such pebbles are known to occur, with a profusion unequalled in the drift gravel, in local beds of Reading age, this difficulty is overcome.

The Lower Eocene gravel of Lane End closely resembles the simpler type of Pebble Gravel found on the higher parts of the Chilterns. The drift gravel, it is true, is usually the coarser, and usually contains a larger proportion of flint pebbles; among its rarer constituents, also, there are a few rocks that I have not yet found in the Reading Beds: nevertheless, it is, on the whole, the sort of drift that would result from a blending of the débris of quartziferous Reading gravels with that of the ordinary Eocene pebble-beds; and after a re-examination of many of the examples in South Oxon and Bucks I am much disposed to think that it has been formed in that manner.

Little novelty can be claimed for this view of the origin of the northern Pebble Gravel. A similar explanation was advanced, in 1900, by Mr. Clement Reid,[*] who, however, did not, in his brief note, offer any suggestion as to the reason why materials rare in all the local Eocene Beds known to geologists at that date were common, and more than common, in the drift. Sir Henry Howarth,[†] too, claimed a Reading Beds-origin for the Westleton shingle of Westleton and Southwold in 1895, but he, also, left untouched that question of the relative frequency of certain rock-pebbles to which Sir Joseph Prestwich, Messrs. Monckton and Herries, Dr. Salter, and I have attached perhaps too much importance.

On the assumption that the simpler sort of quartzose Pebble

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[*] *Summary of Progress of the Geological Survey for* 1899, p. 140. Mr. Reid's note relates more directly to the gravels of the "Stanmore District" and Highgate, in Middlesex. At Stanmore he (or Mr. A. C. J. Cameron) found "rare fragments of Greensand-chert." Dr. Salter states that this material does not occur in the higher, less complex, Pebble Gravel of that neighbourhood, though it does so "plentifully" in the lower, *Proc. Geol. Assoc.*, vol. xix (1905), p. 25. Is Greensand-chert known from any bed indisputably of Eocene age around London?

[†] "On the Shingle Beds of Eastern East Anglia," *Quart. Journ. Geol. Soc.*, vol. li, p. 497.

Gravel on the Chilterns is the wreck of coarse Eocene deposits formerly existing farther to the north, its wide range in altitude on the northern side of the London Basin, and its non-occurrence on the southern, are explicable without recourse to those extensive differential movements in recent times which are a corollary of the marine hypothesis of Prestwich. Originating on the higher part of the northern dip-slope, this drift has, we may suppose, travelled down the incline towards that somewhat ill-defined tract of uneven ground around London where we find its constituents mingling with the red quartzites and other materials from the Midlands, and the chert and ragstone from the Weald

THE HIGHER ZONES OF THE UPPER CHALK IN THE WESTERN PART OF THE LONDON BASIN.

BY LLEWELLYN TREACHER, F.G.S., AND HAROLD J. OSBORNE WHITE, F.G.S.

CONTENTS.

I.—INTRODUCTION.

THE following paper contains the results of an examination of the western part of the London Basin made, during the last two years, for the purpose of determining the zonal features of those divisions of the Chalk which immediately underlie the Tertiary Beds in that region, and also of throwing some light on the nature of the unconformity existing between the two series of strata. The sections to be described are in that part of the Chalk which occurs at the surface within a short distance of the main mass of the Tertiaries, and of the numerous outliers which border it, especially on the west and north sides. The area is limited on the east by a line drawn from near Farnham to near Henley-on-Thames, and extends to Savernake Forest in the west; the whole being comprised within Sheets 267, 268, 283, and 284 of the 1-inch Geological Survey Maps, New Series. [See Sketch Map, Pl. VII.] Owing to the great extent of country to be covered anything like a thorough investigation and comparison of the numerous sections and exposures it has been found necessary to examine would involve an amount of steady work which it has been quite beyond our power to undertake. Having regard, however, to the recent revival of interest in the Chalk we are inclined to think that the outline which we here present may prove useful to other workers in the same field. We hope at no distant date to deal with some of the more interesting districts separately and in greater detail. We accept Dr. Rowe's definition of the higher zones of the Chalk, and in following them up in the field have relied almost entirely on the zoological criteria which he has established for their discrimination. The literature of the Chalk in this area is small, and most of the published works bearing on our subject are referred to in the body of the paper.

II.—THE SOUTHERN BORDER.

The greater part of the Chalk area south-east of Odiham, in Hampshire, is occupied by the zone of *Marsupites testudinarius*, which extends from the main Tertiary boundary southward, beneath the outliers of Horsedown Common and Well, nearly to the edge of the escarpment overlooking the valley of the Wey.

On White Hill, north-west of Well, are two roadside quarries a short distance apart, the lower of which is 15 ft. deep, but was so hidden by talus that the general character of the chalk could not well be made out. Such as could be seen *in sitû* was soft and white, with few flints, and yielded a few plates of *Marsupites*, but on the talus were some blocks of very hard chalk containing fragments of *Inoceramus* and many small oysters. The other pit is at a level of about 30 ft. higher, at the top of the hill, and shows 12 ft. of chalk with lenticular jointing and of irregular hardness. Most of it is fairly soft, but near the base some of the blocks are quite firm and even rocky. Small flints are scattered plentifully throughout, and there are at least three layers of the solid nodular variety, of medium size, and with thin rinds. Fossils are scarce, with the exception of small oysters and fragments of *Inoceramus*, which are common. Green-coated flints occur in the surface-soil.

Similar chalk, with small oysters, can be seen close under the Reading Beds on the north-east side of the Well outlier, in a road-cutting near Stroud Farm. One-third of a mile north-east of this spot, on the north of the lane leading to Travers Farm, is a pit, 10 ft. deep, in rather firm chalk, irregularly jointed, with one course of solid nodular flints about half-way up, and many small ones scattered throughout. Small oysters abound, one specimen of *Echinocorys scutatus*, of an ovate form characteristic of beds at, or close below, the base of the *Actinocamax quadratus*-zone, was obtained here, and a flint cast of a similar form was found on the surface of a field close by. A little farther east, along the lane, at a level of about 20 ft. lower, an overgrown pit in a small valley west of Travers Farm yielded a few blocks of soft chalk in which plates of *Marsupites* were abundant.

One-third of a mile north of this pit, close under the Tertiary outlier of Horsedown Common, a farmyard pit between Swanthorpe Farm and High Croft Copse exposed 12 ft. of chalk of character similar to that of the higher beds at Well. Besides the small oysters, the only fossils found were *Micraster cor-anguinum*, and one specimen of *Echinocorys scutatus*, the shape of which again suggests the proximity of the zone of *Actinocamax quadratus*. It is probable that the chalk in this pit, and in the higher pits at Well, belongs to the lower part of that zone, but in the absence of sufficient zoological evidence we hesitate to assign it definitely thereto, and prefer at present to regard it as the highest part of the zone of *Marsupites*.

Around the outlier of Horsedown Common are many old chalk-pits, mostly, however, now sloped over and difficult of access. On the north-west side, about half-a-mile from the boundary of the Reading Beds, on the east side of a lane north of Roke Farm, there is a good section, 18 ft. deep, of soft white chalk with lenticular jointing. One seam of tabular flint occurs at a sharp angle to the bedding planes, and there are also a few small, solid flints scattered throughout, some of which take the form of flattish cup-shaped sponges. Ferruginous casts of sponges also are not uncommon. Plates of *Marsupites* are plentiful at the base of the section, but become scarce towards the top.

Along the main Tertiary boundary the most easterly exposure noticed was in an old field-pit south-east of Byron's Farm, Crondall, where in one corner, at the top, a recent excavation showed 6 ft. of soft, blocky chalk with a few good-sized solid flints. *Echinocorys scutatus* var. *pyramidatus* and plates of *Marsupites* are common. One mile to the north-west, just inside the park east of Itchel House, is a large pit the face of which was much obscured by talus, only 6 or 8 ft. of the upper part being accessible. The chalk is very soft and much crushed, and plates of *Marsupites* and fragments of *Echinocorys* and *Micraster* are fairly common. As several green-coated flints were observed in the clayey surface-soil it is probable that this is near the upper limit of the chalk, although some little distance from the main mass of the Tertiaries.

One mile west-north-west of the above, and a little to the south of Rye Common, is a large quarry with a perpendicular face of over 30 ft. The chalk is soft and blocky with a few irregular bands of nodular flints and some tabular seams, the latter being at various angles to the bedding planes. This is the pit mentioned by Messrs. Bristow and Whitaker* as abounding in "*Echini* and other fossils," and as showing a dip of 3° nearly due north. The fossils found by us include plates of *Marsupites*, which occur in all parts of the section, and many specimens of *Echinocorys scutatus* var. *pyramidatus*, all more or less broken.

The pits formerly worked between Rye Common and Odiham appeared to be overgrown, and we were unable to obtain any satisfactory evidence of their zonal position, but somewhere in

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* *Geol. Sur. Mem.* on Sheet 12, "Parts of Berks and Hants," p. 18 (1862).

this tract of country the *Marsupites*-band dies out, and its place as the topmost bed of the chalk is taken by the lower division of the zone, the *Uintacrinus*-band. Working westward, this was first noticed in a pit, 12 ft. deep, at the northern end of Wassel's Copse, one mile south-east of Odiham. Plates and brachials of the name-crinoid are common, but few other fossils were found. Flints of medium size occur both scattered and in irregular layers, and the chalk is somewhat firmer than that of the *Marsupites*-band in the pits last-mentioned.

The fine quarry on the south-west side of the town of Odiham appears to be all in the *Uintacrinus*-band, which we estimate to be here over 50 ft. in thickness. At the northern end of the pit, which alone is worked, we obtained a suite of fossils similar to that recorded by Mr. Jukes-Browne* as having been found at Odiham by Messrs. Griffith and Brydone. The chalk is of medium firmness, white and blocky, with few flints, and is much used for top-dressing the soil over the Tertiary country to the north.

The *Uintacrinus*-band is again exposed in a small field-pit on Adams' Farm, east of Greywell, on the northern slope of a hill overlooking the Tertiary country and not far from the boundary. There is also a good section of the same band in a roadside pit, 25 ft. deep, near the summit of Greywell Hill, on the west side. Fossils are fairly abundant, and the jointing of the chalk is very massive at the base of the section.

Remains of *Uintacrinus* were found in pieces of chalk from the talus of an old pit known as Cobbler's Dell, on Huish Farm, Mapledurwell, to the west of which the *Marsupites*-band comes on again. Its absence between this place and Odiham, or its restriction there to a very narrow belt close to the Tertiary boundary (for we have never met with the *Uintacrinus*-chalk in actual contact with the Eocene Beds in this district), may be due to a gentle anticline of late Cretaceous or early Eocene age, from the crest of which the upper part of the *Marsupites*-zone has been denuded.

Around Basing and north of Basingstoke the *Marsupites*-band is much in evidence. The chalk at the bottom of a large pit, or series of workings, the upper parts of which were hidden by talus, on the south side of Hatch Lane, yielded *Echinocorys scutatus*, var. *pyramidatus*, and a few plates of *Marsupites*. A little to the north-west of this pit, at the cross roads near Parker's Farm, about 10 ft. of chalk was visible at the top of an old quarry. The fossils, which are abundant, include *Echinocorys scutatus* var. *pyramidatus*, *Marsupites*, *Conulus* (*Galerites*) *albogalerus* (a small form, in a band, and always crushed), *Ostrea vesicularis*, etc.

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* "Cretaceous Rocks cf Britain" (*Mem. Geol. Survey*), vol. iii, pp. 190-192.

barren band which is sometimes found in the middle of the *Marsupites*-zone.

Such other pits as exist near Inkpen are in the *Micraster cor-anguinum* or lower zones; but at Prosperous Farm, a mile and a half north-west of the village there is a pit showing about 20 ft. of the *Uintacrinus*-chalk. Plates and brachials of the crinoid are abundant in a six-inch band half-way up the section. The beds dip north at 27°, and there is room for 20 or 30 ft. of higher chalk between them and the Tertiary strata.

III.—THE WESTERN END.

Beyond the Shalbourne-Hungerford valley, which marks the western end of the main mass of the Tertiaries, the Eocene Beds occur as a series of outliers separated by rather narrow, steep-sided valleys cut down into the underlying chalk, which is exposed in a fair number of pits. The Bedwyn valley, followed by the Great Western Railway and the Kennet and Avon Canal, divides the district into two parts.

(A.) Between it and the Shalbourne valley is a well-defined Chalk area, with three Tertiary outliers of unequal sizes. The two smaller ones, forming the wooded hills of Wilton Brail and Bedwyn Brail, on the south-west, seem to rest entirely on the *Marsupites*-band, but sections close to their boundaries are scarce. *Marsupites* occurs in several old and badly-obscured workings round the edge of the wood, especially on the east side. East of Castle Copse is a good pit showing the following section:—

		ft.	ins.
	(4) Soil		
READING BEDS.	(3) Mottled Clay	2	6
	(2) Greyish green sand with a few flint pebbles and concretions of iron oxide and "race"... ...	2	6
CHALK.	(1) Soft blocky chalk, with a sharp, slightly waved junction with the overlying beds. *Marsupites* and other fossils, and a few scattered flints ... ... exposed	12	0

The *Uintacrinus*-band is exposed at the bottom of the Bedwyn valley near the third lock south-west of Great Bedwyn, and it may pass beneath the canal there.

The largest of the three outliers extends from Harding Farm on the south to North Standen Farm on the north, a distance of three miles, and rests for the most part on the *Marsupites*-band, but towards the north-west corner this thins off and perhaps disappears, all the sections close to the Eocene boundary at that end being in the *Uintacrinus*-band.

Working round the outlier from Shalbourne westward, we notice first a small overgrown field-pit, three-eighths of a mile north-west of the Church, which has yielded plates of *Marsupites*. No other sections were seen along the south-east side, but in the small valley which runs from Harding Farm to Great Bedwyn there is a section of the *Uintacrinus*-band in a roadside pit south of Folly Farm, and another near the canal by the first lock south-west of Bedwyn. The *Marsupites*-band is exposed in several small pits close to the Tertiary boundary west of Folly Farm, and by the side of Foxbury Wood. Turning the corner of the wood and proceeding northward, we come to a small exposure of chalk close under the Tertiaries in Little Bonning's Copse, south-east of Little Bedwyn. The chalk here is very wet and dirty, the pit being, apparently, in a swallow-hole. It belongs to the *Uintacrinus*-band, but fossils are very scarce. Half a mile farther east, in a field on the north-east side of Barn Copse, are three grassed-over pits in the *Uintacrinus*-band. There is also a large pit, much talused, in the same chalk on the opposite side of the little valley west of Brickhouse Copse, Stype Wood. At the north end of this wood is another section showing 5 ft. of soft, clean chalk, massive at bottom and finely jointed at the top. There are a few scattered flints, and *Uintacrinus* is fairly common. On the east side of the outlier *Marsupites* is found in a pit near the mill, north-west of Slope End.

(B.) In the sub-district west of Bedwyn we have traced the zone of *Marsupites* as far as the depression which runs through Tottenham Park, on the east side of Savernake Forest from Durley northward towards the Froxfield valley at Knowle. It appears to be thickest at the south-east corner, near Crofton, and to thin off westward and northward. Some old grassed-over pits in Tottenham Park, between Durley and the Warren Farm, are in the *Uintacrinus*-band, but the presence of the upper part of the zone has not been proved west of the Eocene outlier of Bedwyn Common.

In the valley to the east of this outlier, running parallel to the depression above mentioned, the *Marsupites*-band is exposed in an old pit on the north-east side of the reservoir, and has there yielded plates of *Marsupites*, and one broken specimen of *Actinocamax granulatus*. Farther down the valley, a pit in a wood west of Stock House shows 12 ft. of soft chalk divided into lenticular masses by seams of crushed chalk. Flints are very few and fossils are scarce; plates of *Marsupites* and fragments of *Echinocorys* being the chief ones noted. A little farther north, to the west of Bewley Farm, is another pit in which fossils, including *Marsupites*, *Echinocorys scutatus* var. *pyramidatus* and *Ostrea vesicularis*, are unusually abundant. Two-thirds of a mile north of this, on the southern slope of Horsehall Hill, is a pit, 15 ft. deep, in the *Uintacrinus*-band. This section does not show quite the highest chalk in the hill, which may have a thin capping of the *Marsupites*-band. Such other pits as could be found to the north and west of Upper Horsehall Hill are in the zone of *Micraster cor-anguinum*.

On the west side of the Bedwyn valley, between the canal and the Tertiary boundary, good sections of the *Marsupites*-zone are scarce. The best is at Lower Barn, north-west of Crofton. This shows about 12 ft. of the *Marsupites*-band with many plates of the name-fossil. Nearer Great Bedwyn the chalk of this part of the zone at, or close to, its junction with the Tertiaries, has been converted into a very hard, fine-grained limestone with a conchoidal fracture. It contains fragments of *Inoceramus*-shell, occasional specimens of *Actinocamax granulatus* and, in a road-cutting up Chisbury Hill, numerous plates of *Marsupites*. Under the name of "roach," the occurrence of this rock was noticed, many years ago, by Mr. Whitaker* who described it as "a confused mass of pieces of hardened (? silicified) and somewhat flaggy chalk," overlying a bed of reconstructed chalk. At the present time the stone, which is much used for road-metal, is nowhere visible strictly *in situ*, as the detached blocks occurring in the soil or drift, rather below its outcrop, alone are worked. Although it contains a few small flints, its hardness is not due to silicification, as samples dissolve readily in weak mineral acid, leaving only a slight residue as fine brown mud. Mr. Jukes-Browne, who has kindly examined some samples, informs us that the induration is due to partial crystallisation.

IV.—THE NORTHERN SIDE.

(A.) On the northern side of the main mass of the Tertiaries, east of the Shalbourne Valley, and south of the Kennet, nearly the whole of the chalk area is occupied by the *Marsupites*-zone; the zone of *Micraster cor-anguinum* coming to the surface only along the Kennet Valley near Hungerford. The *Marsupites*-band occurs, as an almost flintless chalk, in a small pit near Slope End, on the east side of the road from Hungerford to Shalbourne. About a mile to the north-east of this pit there is a good section, 25 ft. deep, near Anville's Farm, and not many yards distant from the Tertiary boundary. Plates of *Marsupites* are found at all levels, and there is a band of *Echinocorys scutatus* var. *pyramidatus* about half-way up. The chalk is soft and blocky, with some layers of crushed chalk, and there are numerous small globular flints scattered throughout, in addition to the nodular forms. *Marsupites* was noticed also in fragments of chalk on the slope of a grassed-over pit in the park, at a point about one-third of a mile south-west of Inglewood House.

North of this most of the chalk appears to belong to the *Uintacrinus*-band. There is a pit 8 ft. deep in firm, finely-

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* *Quart. Journ. Geol. Soc.*, vol. xvii (1861), p. 527.

jointed chalk by the roadside west of Little Templeton. One layer of large flints occurs near the top, but fossils are scarce. A large disused pit in the park, north of Inglewood House, showed, on the east side, 8 ft. of flaggy chalk with very few fossils. On the west side, at a slightly lower level, was a small exposure of soft, blocky chalk in which remains of *Uintacrinus* were extremely abundant, the plates and brachials occurring in bunches, much as in the Margate cliffs.

Farther east, in the immediate neighbourhood of Kintbury, is one of the most interesting districts in our area; containing, as it does, not only good exposures of both divisions of the *Marsupites*-zone, but also a fine section of the lower part of the zone of *Actinocamax quadratus*. In the large pit by the canal near Kintbury Mill, there is a section about 30 ft. deep in the *Uintacrinus*-band. The chalk is white, soft, and blocky, and is worked for the manufacture of whiting. Nodular flints are scattered sparsely throughout, and there are a few seams and oblique veins of the tabular variety. Fossils are scarce, but *Act. verus* was noted. In the village, at the higher level, small exposures in cottage gardens on the south side of the Newbury road give evidence of the presence of the *Marsupites*-band.

At Laylands Green, three-eighths of a mile south of the mill section, is the pit which was visited by the Geologists' Association on June 21st, 1902, and briefly described by one of us in the report of that excursion.* The few fossils then found suggested that the chalk belonged to a higher zone than that of *Micraster cor-anguinum*, but at the time its exact position was left undetermined. Further examination of the section under more favourable conditions (not the least of which is the recently-increased depth of the pit) has proved beyond doubt that it belongs to the zone of *Actinocamax quadratus*, part of which here occurs in an outlier of small extent, but of considerable thickness. The chalk in the Laylands Green pit dips S.W., at about 5°, and measured at right angles to the bedding, about 40 ft. is exposed. Its character varies from blocky to lumpy, and from firm to soft, in different parts of the section. In the lower part are several seams of tabular flint; nodular forms occur scattered throughout, and near the top there is a layer of the large cylindrical variety. In the upper part of the pit there are two bands of hard rocky chalk containing casts of sponges. *Offaster pillula* is most abundant in the lower part of the section, which was not exposed at the time of the excursion, but it is also found higher up and in the rock-bands. *Actinocamax quadratus* occurs sparingly in the higher beds. The usual zonal forms of Echinocorys are plentiful and frequently of very small size.

Half-a-mile west-south-west of the Laylands Green pit, a small

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* *Proc. Geol. Assoc.*, vol. xvii, 1902, p. 388. "Cretaceous Rocks of Britain," vol. iii, p. 203. *Mem. Geol. Survey*, 1904.

exposure in a field showed 5 ft. of flaggy chalk with scattered flints, and one discontinuous layer of large cylindrical nodules at the top. Among the few fossils found were three specimens of *Actinocamax granulatus*. The section is probably about 20 ft. below the Tertiaries, which come on a short distance to the south.

The *Marsupites*-band is well shown less than half-a-mile south-east of Laylands Green in a pit 15 ft. deep, at Hampstead Holt Farm, only a few feet below the base of the Eocene Beds. The chalk is in blocks of medium size with stained joints. *Marsupites* is very abundant, four nearly complete tests having been observed, one containing a number of brachial and tegmenal ossicles. Unfortunately the condition of the chalk makes it impossible to extract the specimens unbroken.

At Irish Hill, rather more than half-a-mile east of the Laylands Green pit, is a much degraded section of the *Marsupites*-band. The chalk shown is finely jointed, and fossils are very scarce. This pit is some distance below the Tertiaries; 20 ft. at least.

About one mile and a quarter farther to the south-east, near the village of Hampstead Marshall, in a small inlier of Upper Chalk surrounded by clays of the Reading Beds, an old pit at the bottom of the valley shows 10 ft. of the *Marsupites*-band. The chalk is of a somewhat unusual character for this zone, being greyish and lumpy rather than white and blocky. The rock is much stained with clay, which has penetrated along the joint planes. Fossils are difficult to find, but a few plates of *Marsupites* were obtained after some search.

(B.) North of the Kennet, in and west of the Hungerford district, the Tertiary Beds appear to rest directly on chalk of the *Micraster cor-anguinum*-zone. At Hopgrass, one mile west-north-west of Hungerford, near the top of the ridge between the Kennet and the Bedwyn Valley, is a pit 25 ft. deep in chalk, with regular layers of solid nodular flints. About 15 ft. from the surface there is a band of yellow, rocky chalk, and fossils characteristic of this zone are fairly common throughout the section. A short distance to the north, at a slightly higher level, the pits in the brickyard show clay of the Reading Beds piped into the underlying chalk, which, where exposed, is in a crushed condition. No distinctive fossils were seen *in situ*, but in the surface soil close by we found a flint cast of *Echinocorys scutatus* var. *striatus*—a form which, throughout our area, seems to be restricted to the extreme upper part of the zone of *Micraster cor-anguinum*, and to the base of the *Uintacrinus*-band.

Nearly four miles east-north-east of Hungerford, near the hamlet of Elcot, the *Uintacrinus*-band is exposed in a small pit, 12 ft. deep, close to the Tertiary boundary. The chalk is soft and white, and flints are small and scarce. Both *Uintacrinus* and

Bourgueticrinus are common fossils here. In Benham Park, one and a half miles north-west of Newbury, there is a small pit at the edge of a copse, showing 12 ft. of soft chalk with scattered flints. *Uintacrinus* occurs sparingly.

The most easterly sections of the *Marsupites*-zone observed were in the two well-known pits at Shaw brickyard, north-east of Newbury, where a varying thickness of chalk is exposed beneath the Reading Beds. The topmost layers are discoloured and hardened in places, and riddled with curved tubular borings filled with the overlying pebbly green sand. The chalk between the borings abounds in plates and brachials of *Uintacrinus*. Two open courses of flints occur, the lower of which, about 10 ft. from the top, may be taken as the downward limit of the *Uintacrinus*-band, as below it no traces of the name-fossil have been observed, and the *Micraster cor-anguinum*-chalk immediately underlies the Reading Beds a little to the north.

The *Uintacrinus*-chalk appears to die out beneath the long Tertiary outlier which extends from Speen to beyond Wickham, along the west side of the Lambourn Valley, all the sections we have seen near its north-east border being in the zone of *Micraster cor-anguinum*.

Beneath the next Tertiary outlier on the east, between the valleys of the Lambourn and the Winterbourne, there exists a small outlier of the zones of *Marsupites* and *Actinocamax quadratus*. The chalk is of an unusual character, being in varying degrees phosphatic, and containing several rock-bands. Open sections are scarce and small, and for evidence of its lateral extension we have had to rely largely on small excavations made in the fields by ourselves for the purpose. Three sections may be noticed. The first is in a roadside pit in Hangmanstone Lane, about a quarter of a mile north of Boxford Church. The beds have a strong dip to the south-east, and they are all in the upper part of the *Micraster cor-anguinum*-zone, although the *Uintacrinus*-band must come on not far above the top of the pit. There are two rock-bands shown, the upper of which contains many small oysters; and the chalk is distinctly phosphatic in places. The *Uintacrinus*-band is exposed in a small roadside pit, one-eighth of a mile east of Boxford Rectory, where 8 ft. of soft, crushed chalk is shown, with few flints and very few fossils.

The most interesting exposure in the whole outlier is in a small pit in the middle of a field a quarter of a mile north-west of Winterbourne Church. This shows about 12 ft. of chalk belonging to the zones of *Marsupites* and *Actinocamax quadratus*. Both zones are more or less phosphatic, and very fossiliferous. No flints were seen *in situ*, but there are two rock bands, the higher of which marks the junction of the zones. In, and for an inch or two above, this band *Actinocamax granulatus* is extra-exposure in a field showed 5 ft. of flaggy chalk with scattered flints, and one discontinuous layer of large cylindrical nodules at the top. Among the few fossils found were three specimens of *Actinocamax granulatus*. The section is probably about 20 ft. below the Tertiaries, which come on a short distance to the south.

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The most interesting exposure in the whole outlier is in a small pit in the middle of a field a quarter of a mile north-west of Winterbourne Church. This shows about 12 ft. of chalk belonging to the zones of *Marsupites* and *Actinocamax quadratus*. Both zones are more or less phosphatic, and very fossiliferous. No flints were seen *in situ*, but there are two rock bands, the higher of which marks the junction of the zones. In, and for an inch or two above, this band *Actinocamax granulatus* is extra-ordinarily abundant, and is associated with many specimens of *Echinocorys scutatus*.

Besides the rock bands exposed in the pits many patches of rocky chalk have been detected cropping out at the surface on both sides of the hill. The beds down to the base of the *Uintacrinus*-band are overstepped by the Tertiaries near Wyfield Farm on the north, and under Basford Hill on the south, and are cut off on west and east by the valleys of the Lambourn and the Winterbourne, the extent of the whole outlier being less than one square mile.*

Along the border of the main mass of the Tertiaries north-east of Newbury, and around the numerous outliers which exist on the hill-tops at various distances from it, we have not observed any chalk belonging to a higher zone than that of *Micraster cor-anguinum*. At Yattendon, a small pit by the side of the road to Manstone Farm is close to the base of the Reading Beds, and shows 12 ft. of chalk with layers of solid flints. In the upper half of the section the chalk is crushed and the flints shattered. Fossils are numerous, especially spines of several species of *Cidaris*.

At Upper Basildon, chalk is obtained from a shaft sunk through the Reading Beds in the brickyard. The fossils found were similar to those from Yattendon, and indicate the upper part of the *Micraster cor-anguinum*-zone. There are pits also at Englefield and Stanford Dingley, at about the same horizon.

In a now disused brickyard on the east side of the village of Theale about 15 ft. of chalk is exposed beneath the Reading Beds. It is worked for lime-burning, and contains many regular layers of solid nodular flints. Fossils are fairly numerous, especially Echinoderms.

At Westwood, Tilehurst, to the north-east of Theale, there is a chalk pit 25 ft. deep, the top of which can be but little below the base of the Tertiaries. Fossils are common and flints are plentiful, both scattered and in regular layers. Many of them, especially the scattered ones, are of the cavernous variety, and contain "meal" rich in *Bryozoa*. Flints of this character are very rare in the upper part of the *M. cor-anguinum*-zone of our area, the only other place we have noticed them being at Winterbourne, just below the *Uintacrinus*-band, where, however, *Bryozoa* are by no means common.

The large quarries at Chazey Farm and near Caversham Church, described by Dr. Barrois† (the latter as being in his zone of *Marsupites*), are both clearly some distance below the upper limit of the zone of *Micraster cor-anguinum*. Cavernous flints occur at both places, and *Bryozoa* are fairly common in them at

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* For a detailed account of this outlier see paper by the present writers in *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 499.

† "Recherches sur le Terr. Crét. Sup. de l'Angleterre, etc.," p. 148, 1876.

Chazey Farm: the species, however, do not altogether correspond with those from Westwood, Tilehurst, on the opposite side of the Thames. At Caversham these organisms are either absent or very rare.

Several sections exposed in temporary excavations for drainage and other purposes at the western end of the town of Reading have shown the ordinary flinty *M. cor-anguinum*-chalk immediately underlying the Eocene Beds.

Chalk was formerly exposed beneath the Reading Beds by the side of the Thames in Holme Park, Sonning. Some lumps taken from this locality, when rubbed down, yielded many fragments of *Bryozoa*, but few other fossils.

At Ruscombe Lake, on the north side of the Great Western Railway, about a mile east of Twyford Station, a small pit close to the old brickyard shows 10 ft. of finely-jointed, iron-stained chalk beneath the Reading Beds. Small finger-shaped flints are scattered throughout, and there are two thin tabular seams. The chalk is soft and fine-grained, and contains an unusually large proportion of perfect specimens of Foraminifera. Ferruginous casts of sponges are common, but other fossils are scarce. One broken guard of *Actinocamax verus* was found. Similar chalk is exposed in the railway cutting a mile or two farther east, where a flint cast of an Ammonite,[*] *Haploceras leptophyllus* (Sharpe), was found by a workman during the widening of the line in 1903. A list of the *Foraminifera* from this cutting has been published by Mr. E. Heron-Allen, F.L.S.[†]

The stratigraphical position of the Ruscombe Lake chalk would appear to be at the top of the *Micraster cor-anguinum*-zone, and immediately below the *Uintacrinus*-band, which probably comes in beneath the Tertiaries not very far to the south.

At Warren Row, two miles and a half north-east of Ruscombe, and just outside our area, is a small section showing the junction of the Chalk with the overlying Reading Beds.[‡] The former is well down in the *Micraster cor-anguinum*-zone, the flints being large and solid and in frequent regular layers.

V. CONCLUSION.

As will be seen from the foregoing account, we have either determined, or confirmed the existence, in this area, of the following sub-divisions of the Upper Chalk above that part of the zone *M. cor-anguinum* which is characterised by regular courses of solid nodular flints:—

1. A group of beds, about 20 to 30 ft. thick, consisting of soft

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[*] *Proc. Geol. Assoc.*, vol. xvii, p. 177.
[†] "Prolegomena towards the study of the Chalk Foraminifera," 8vo., London, 1894.
[‡] *Proc. Geol. Assoc.*, vol. xvii, p. 179.

chalk with comparatively few and scattered flint-nodules and not infrequent seams and veins of tabular flint. These beds belong to the *M. cor-anguinum*-zone, but have many characters in common with the *Uintacrinus* chalk above. In them the large form of *Echinocorys scutatus* figured by Wright* as var. *striatus* seems fairly common, and remains of *Conulus albogalerus* are generally abundant. A pyramidate shape-variation of *Echinocorys*, like that occurring in the *Marsupites*-zone, has been noticed in two or three places.

2. The zone of *Marsupites*, divisible, as usual, into an *Uintacrinus*-band below and a *Marsupites*-band above. As in other places in the south of England, the *Marsupites*-band admits of sub-division into two parts. The upper part, which includes perhaps one fifth of the total thickness of the band, is, in this area, distinguished from the lower part chiefly by:

(*a*) the absence, or extreme scarcity, of *Marsupites testudinarius*.

(*b*) the presence of *Actinocamax granulatus*, a fossil we have rarely found in association with *Marsupites*; and by

(*c*) the presence of depressed pyramidate and sub-ovate shape-variations of *Echinocorys scutatus*.

With reference to the last-named species it may be mentioned that the angulation of the apex of the test in the pyramidate variety characteristic of the *Marsupites*-zone is most pronounced in the *Uintarinus*-band. Further, that the average size of the variety is appreciably smaller in North Hants, Wilts, and Berks than in the Isle of Thanet.

In the western part of the London Basin the larger fossils of the *Marsupites*-zone have a somewhat sporadic distribution. Here and there we have encountered very barren beds, mostly in the *Uintacrinus*-band. Generally speaking, identifiable organic remains are far less common than in chalk of the same age occurring farther east.

We estimate the thickness of the zone to be at least 100 ft. near Crondall, Hants, at the south-eastern limit of the area; about 60 ft. at Kintbury, Berks, and Great Bedwyn, Wilts; and 30 to 40 ft. in the outlier between Boxford and Winterbourne, Berks. In the last case, however, the lithological conditions are abnormal. At Kintbury and Winterbourne the entire zone is represented, so that the northward and north-westward attenuation of this division of the Chalk formation, within the tract of country covered by the present paper, admits of no question. At Odiham, Hants, the *Uintacrinus*-band alone has a thickness greater than that of the whole zone at Winterbourne.

3. The zone of *Actinocamax quadratus*—the lower beds of which have been definitely recognised by us only in the two

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* "Cretaceous Echinoderms," *Pal. Soc.*, 1882, plate 77, fig. 7.

small outliers of Kintbury and Winterbourne. At the former place, where there is at least 50 ft. of the zone, the lithological conditions differ but slightly from those obtaining in the *A. quadratus*-chalk of the Hampshire Basin. The Winterbourne patch is more or less phosphatic, and its maximum thickness is probably not more than half that provisionally assigned to the Kintbury development.

It is probable that some of this chalk occurs about Well and Horsedown, near Crondall; and there may be a little also at Old Basing and near Great Bedwyn, but we have not found the zonal fossil, *Offaster pillula*, at any of these places.

Superficial as much of it admittedly has been, our examination of the higher zones of the Chalk in the western part of the London Basin has yet thrown a good deal of light on the nature of the unconformity between the Cretaceous and Eocene strata in that area. To ascertain the structural relations of these rocks was, indeed, one of the main objects of this cursory survey.

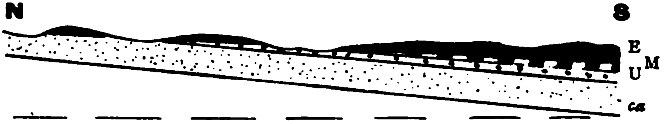

FIG. 2.—DIAGRAM TO SHOW THE GENERAL RELATIONS OF THE CHALK AND EOCENE BEDS ON THE NORTH SLOPE OF THE LONDON BASIN, IN BERKSHIRE.

E.—Eocene Beds.
M.—*Marsupites*-band.
U.—*Uintacrinus*-band.
ca.—*M. cor-anguinum* zone.

One broad fact which we have established is the general overstepping of the higher beds of the Chalk by the Eocene strata in a northward direction. Thus, having traced the *Marsupites*-zone along the southern border of this tract from Crondall to Savernake, we entertain little doubt that its outcrop is continuous between those places, as Dr. Barrois'* map indicates; but on the northern side of the area we find that most of the outliers and part of the main mass of the Eocene rocks rest upon divers portions of the older, *Micraster cor-anguinum*-zone, the *Marsupites*-chalk not appearing to the east of Shaw, near Newbury. To the west of Shaw the chalk of the *Marsupites*-zone, capped in places by beds of *Act. quadratus* age, extends across the narrow belt of country to which the main body and larger western outliers of the Eocene formations are there restricted; and it is in this part of the country that the character of the overstep is most clearly shown (Fig. 2).

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* "Recherches sur le Terr. Crét. Sup. de l'Angleterre, etc.," plate 1. It should be noted that the *Marsupites*-zone of Dr. Barrois generally included, with the modern zone of that name, an uncertain but very considerable thickness of Chalk presently assigned to the zones of *Actinocamax quadratus* and *Micraster cor-anguinum*.

The northward range of the *Marsupites*-zone beneath the Eocene cover in the eastern half of our area has nowhere been determined. From the re-emergence of this chalk (probably in an outlier) at Taplow, in South Bucks, and from the varying character of the older chalk visible at the boundary of the main mass of the Reading Beds east of Theale, however, we infer that the northern limit of the zone follows a sinuous line having a general eastward and east-north-eastward trend from Newbury.

The transgressive relation of the Eocene to the Chalk, attributable to a gentle southward tilting and to subsequent planation of the latter in late Cretaceous or early Eocene times, is somewhat complicated by the effects of minor foldings which preceded or accompanied this regional disturbance. Planed across by erosion before the deposition of the Reading Beds, the small flexures have given rise to local uncomformities and to the phenomenon of outliers. We have not recognised any inliers, although some no doubt exist. Good examples of this secondary or trivial sort of discordances occur in the vicinity of Kintbury, and of Winterbourne, in Berks. At the latter place we have ascertained that the Reading Beds pass from the *Uintacrinus*-band to the *Act. quadratus*-zone, and back again, in the space of little more than half a mile. Such local unconformities have been recognised in the north of France, and most probably occur in the more eastern parts of the London Basin (besides the Taplow district), and in the Hampshire Basin as well. We hope that those members of the Association who are examining the Chalk in their respective districts will look out for them, and describe any that they notice.

Our thanks are due to Dr. A. W. Rowe, Mr. A. J. Jukes-Browne, and Dr. G. J. Hinde for advice, especially at the commencement of our undertaking; to Mr. W. D. Lang for help in identifying the Cyclostomous Bryozoa; to Mr. H. L. Hawkins for assistance in field work; to various quarrymen, and to owners and occupiers of land, too numerous to mention individually, with all of whom our relations have been of an amicable nature.

VI.—LIST OF FOSSILS.

The list of fossils is divided into five columns, as follows:

1. From certain sections of the *Micraster cor-anguinum*-chalk with regular layers of solid nodular flints, which show either its actual contact with the Eocene Beds or its junction with the overlying chalk. Principal examples: Yew Tree Farm, Kingsclere, Ecchinswell, Whitway, Hopgrass, Boxford, Yattendon, Theale and Warren Row.

2. The passage-bed from the flinty part of the *Micraster co*

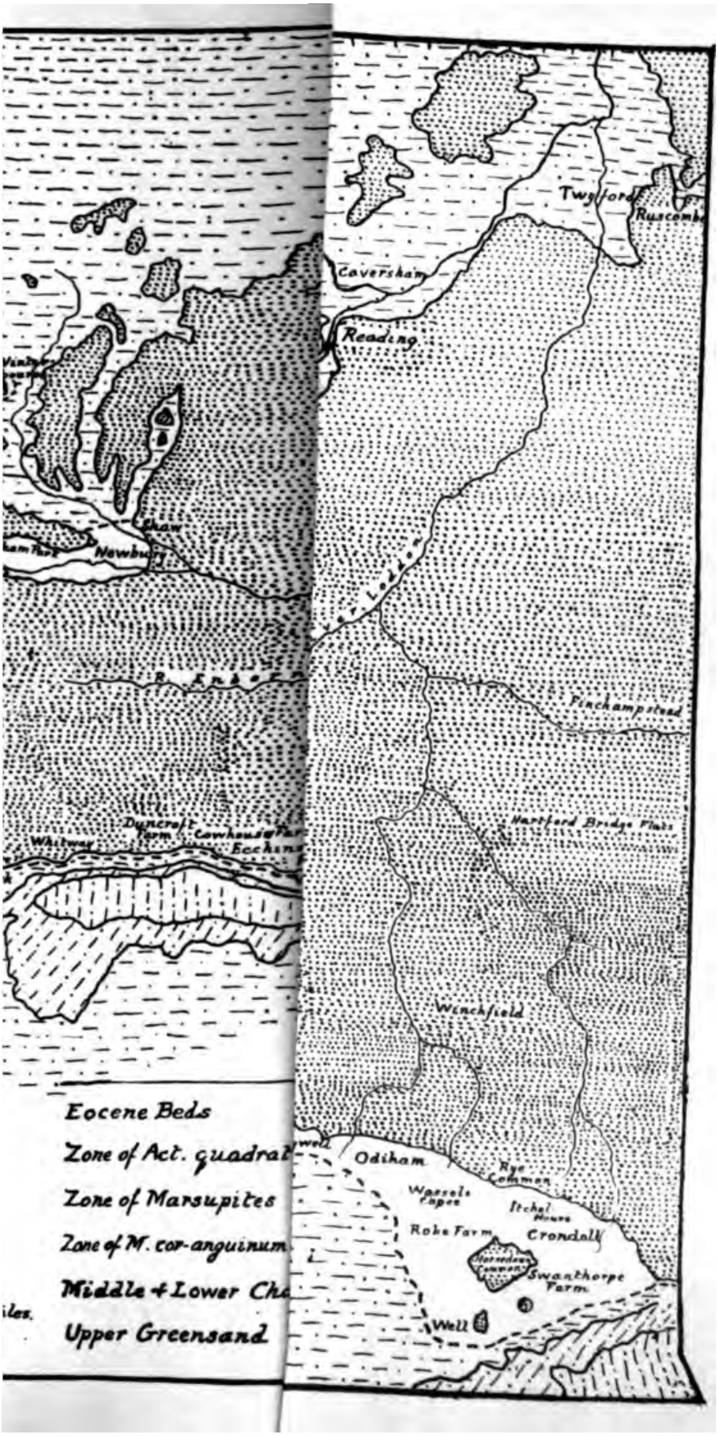
anguinum-zone to the *Uintacrinus*-band. Examples: Yew Tree Farm, Ecchinswell, Cowhouse Farm, Whitway, Shaw, Boxford, Ruscombe Lake and G.W.R. cutting.

3. The *Uintacrinus*-band.
4. The *Marsupites*-band.
5. The *Actinocamax quadratus*-zone of Kintbury and Winterbourne.

	1	2	3	4	5
Corax falcatus, Ag.	...	...	...	×	...
Corax pristodontus, Ag.	×	...	...	...	×
Lamna appendiculata, Ag.	×	×	...	×	...
Oxyrhina Mantelli, Ag.	...	...	...	×	×
Pollicipes glaber, Römer.	...	...	×	...	...
Scalpellum fossula, Darw.	...	...	...	×	...
Scalpellum maximum, Sow.	×	×	×	...	...
Ammonites (*Haploceras*) *leptophyllus*, Sharpe	... ...	×	...	...	...
Actinocamax granulatus (Blainv.)	...	...	...	×	×
Actinocamax quadratus (Defr.)	...	...	...	...	×
Actinocamax verus, Miller	...	×	×	×	...
Exogyra sigmoïdea, Reuss.	...	×	...	...	...
Inoceramus Cuvieri, Sow.	×	×	×	×	×
Lima Hoperi (Mant.)	×	...	...	...	...
Ostrea hippopodium, Nilss.	...	×	...	×	...
Ostrea lateralis, var. *striata*, Nilss.	...	?	...	...	×
Ostrea normaniana, d'Orb.	...	×	...	×	...
Ostrea vesicularis, Lam.	×	×	×	×	×
Ostrea wegmanniana, d'Orb.	...	...	×	×	...
Pecten cretosus, Defr.	×	×	×	×	×
Pecten quinquecostatus, Sow.	×	×	...	×	...
Plicatula sigillina, S. P. Wdw.	×	×	×	×	×
Spondylus latus (Sow.)	...	×	×	...	×
Spondylus spinosus (Sow.)	×	...	...	×	×
Teredo amphisbæna, Sow.	...	×	...	×	...
Crania egnabergensis, Retz.	×	...	...	...	×
Crania Parisiensis, Defr.	...	...	×	×	...
Kingena lima (Defr.)	...	×	×	×	...
Rhynchonella limbata (Schloth.)	...	...	×	...	...
Rhynchonella plicatilis (Sow.)	×	×	×	×	...
Rhynchonella reedensis, Eth.	...	×	×	×	×
Terebratula carnea, Sow.	×	...	...	...	...
Terebratula semiglobosa, Sow.	×	...	...	...	...
Terebratulina Rowei, Kitchin	...	...	×	...	...
Terebratulina striata (Wahl.)	×	×	×	×	...
Thecidea Wetherelli, Morris	...	×	...	...	×
Berenicea papyracea (d'Orb.)	...	...	×	...	...
Berenicea polystoma (Römer)	...	×	...	...	...
Berenicea regularis (d'Orb.)	...	...	...	...	×
Clausa francqana, d'Orb.	...	×	×	...	×
Clausa globulosa (d'Orb).	×	×	×	...	...
Crisina cenomana, d'Orb.	×	...	×	...	×
Crisina unipora d'Orb.	...	×	×	...	×
Entalophora Pergensi, Greg.	...	...	...	...	×
Entalophora virgula (Hag.)	...	...	×	...	×
Idmonea alipes, Greg.	...	×	×	×	...

	1	2	3	4	5
Lichenopora irregularis, d'Orb.	...	×	...	...	...
Meliceritites Lonsdalei, Greg.	...	...	×	...	...
Nodelea durobrivensis, Greg.	×	...	...	...	...
Proboscina angustata (d'Orb.)	...	×	...	...	...
Proboscina crassa (Römer), var. *alectodes*	...	...	...	...	×
Proboscina elevata (d'Orb.)	...	...	×	...	...
Proboscina radiolitorum (d'Orb.)	...	...	×	×	...
Spiropora verticillata (Goldf.)	×	...	...	...	...
Stomatopora gracilis (M. Edw.)	...	...	×	×	×
Stomatopora granulata (M. Edw.)	...	×	×	...	×
Tervia Gamblei, Greg.	...	×	×	...	...
Tervia subgracilis (d'Orb.)	×	×	...	...	...
Truncatula aculeata (Mich.)	...	×	...	...	...
Cribrilina pygmea (d'Orb.)	...	...	×	...	×
Eschara cenomana, d'Orb.	...	...	...	×	...
Eschara Danae, d'Orb.	...	...	×	...	...
Eschara Lamarcki, Hag.	×	×	×	×	×
Membranipora argus (d'Orb.)	×	...	...	...	...
Membranipora dentata (d'Orb.)	×	...	...	...	...
Membranipora echinata (d'Orb.)	...	...	...	×	...
Membranipora elliptica, Reuss	×	×	×	×	...
Membranipora grandis (d'Orb.)	...	...	...	×	×
Membranipora monilifera (d'Orb.)	...	...	×	...	...
Micropora confluens (Reuss.)	...	...	...	×	×
Vincularia (*cf.*) *longicella*, d'Orb.	...	...	×	...	×
Serpula fluctuata, S. Woodw.	...	...	×	×	...
Serpula granulata, Sow.	...	×	...	...	...
Serpula ilium, Sow.	×	...	...	...	...
Serpula plana, S. Woodw.	×	×	×	×	×
Cidaris clavigera, Kœnig.	×	×	...	...	...
Cidaris hirudo, Sorig.	×	×	×	...	...
Cidaris perornata, Forbes	×	×	...	...	...
Cidaris sceptrifera, Mant.	×	×	×	...	...
Cidaris serrifera, Forbes	×	...	...	...	...
Cyphosoma koenigi (Mant.)	×	×	...	...	...
Cyphosoma spatuliferum, Forbes	×	...	...	...	...
Echinocorys scutatus, Leske	×	×	×	×	×
Echinocorys scutatus, var. *gibbus*	...	...	...	...	×
Echinocorys scutatus, var. (cf.) *pyramidatus*	...	...	×	×	...
Echinocorys scutatus, var. *ovatus*	×	...	×	...	×
Echinocorys scutatus, var. *striatus*	...	×	×	...	...
Conulus (*Galerites*) *albogalerus*, Leske	×	×	×	×	...
Epiaster gibbus (Lam.)	×	...	...	...	...
Helicodiadema fragile (Wilt.)	×	×	...	×	...
Hagenowia (*Infulaster*) *rostratus* (Forbes)	...	...	×	...	...
Micraster cor-anguinum, Leske	×	×	×	×	×
Micraster cor-anguinum, var. *rostratus*	...	...	...	×	×
Offaster pillula (Lam.)	...	...	...	...	×
Calliderma latum (Forbes)	...	...	×	...	...
Metopaster Parkinsoni (Forbes)	×	×	×	...	...
Ophiura serrata, Römer	...	×	...	...	...
Pentaceros bulbiferus (Forbes)	×	...	...	...	...
Pentaceros pistilliferus (Forbes)	×	...	...	...	...
Pentagonaster megaloplax, Sladen	...	×	×	×	...
Bourgueticrinus	×	×	×	×	×
Bourgueticrinus, nipple-headed var.	...	...	×	×	...
Marsupites testudinarius, Schloth	...	...	...	×	...

…e White's paper on "The High



	1	2	3	4	5
Pentacrinus	×	×	×	...	×
Uintacrinus	...	...	×	...	...
Cœlosmilia granulata, Dunc.	...	...	...	...	×
Cœlosmilia laxa, E. & H.	...	...	...	...	×
Epiphaxum auloporoides, Lonsd	...	...	...	×	...
Parasmilia centralis, Mant.	×	×	×	...	×
Spinopora Dixoni, Lonsd.	×	×	...	×	...
Pharetrospongia Strahani, Sollas.	...	×	×	...	...
Porosphæra globularis (Phill.)	×	×	×	×	×
Porosphæra nuciformis (Hag.)	...	...	×	×	×
Porosphæra patelliformis, Hinde	×	×	×	×	...
Porosphæra pileolus (Lam.)	...	...	...	...	×
Coscinopora infundibuliformis, Goldf.	...	×	...	×	...
Coscinopora quincuncialis (T. Smith)	...	×	...	×	...
Plinthosella squamosa, Zittel	×	×	×	...	...
Plocoscyphia convoluta (T. Smith)	×	×	...	...	...
Siphonia koenigi (Mant.)	...	...	...	×	...
Ventriculites infundibuliformis, S. Woodw.	...	..	...	×	×
Ventriculites radiatus, Mant.	...	...	...	×	×

ON THE RHÆTIC AND CONTIGUOUS DEPOSITS OF DEVON AND DORSET.

By L. RICHARDSON, F.G.S.

(*Read July 7th, 1906.*)

IN this communication will be found a description of the Rhætic Series as developed in Devon and Dorset.

The superficial extent of the beds in these counties is not great, occupying but a small area contained within a circle with a seven mile radius and having Axminster as the centre.

The Rhætic Beds do not occur beneath the Cretaceous rocks to the west of a line connecting Seaton and Taunton, except in Somerset near Pitminster. Their very irregular boundary-line lies to the east thereof. At first, when traced eastwards, they appear parting the Keuper and Selbornian deposits, but only for a short distance, as beds younger than the Rhætic soon intervene.

This incoming of beds is very well seen along the coast, and is due to their having been uplifted in the west in pre-Cretaceous times ; planed by the Cretaceous Sea ; and, as the area subsided, to the Cretaceous deposits overstepping the outcrops of the older formations.

In the neighbourhood of Axminster the rivers and streams have cut through the Cretaceous beds, and in places the underlying Lias and Rhætic. Unfortunately, however, the outcrop of the Rhætic is seldom well seen owing to the thick accumulations of chert and flint, which have been derived from the higher ground and strewn over the hill-slopes, and the more regularly-distributed rolled material which constitutes the valley-gravels.

The natural sections along the coast afford the best views of the beds under consideration. But even here not all the details which are required can be obtained, for, as is well known, extensive landslips have occurred. Frequently great masses of detached rock obscure the median portion of the vertical sections, and their denuded precursors stretch seawards, hiding the lower portions under an accumulation of mud and rubble.

The best section in the district dealt with in this paper, and covered also by the Geological Survey Memoir on "The Geology of the Country near Sidmouth and Lyme Regis," is at Culverhole. It is not, however, a continuous section. The Rhætic Black Shales, with the Bone-Bed at their base, are seen overlying the marls in the steep bank bordering the beach on the left (or west) ; on the right (east), in a slipped mass which has moved bodily forward, the succession from a massive *Pecten*-Bed (Bed 11) to the Cotham Marble is visible, while a little way up the slope, and also on the right, the sequence from the marls beneath the

Estheria-Bed to the basement-beds of the White Lias can be observed.

Culverhole.—This section has been referred to by several authors.* In 1860 Dr. T. Wright gave the measurements of the principal component beds of the *Avicula-contorta* Zone,† but it was not until 1899 that it was described in anything like detail, when Mr. H. B. Woodward, F.R.S., dealt with it in a report of an excursion of the Geologists' Association.‡ This year (1906) the record printed in the "Proceedings" of the Geologists' Association is reproduced in the *Survey Memoir* on the district with some additional remarks.§

A detailed section is given in Table I (facing p. 406). Since the whole of the Rhætic Series is not present at Culverhole, in order to show at a glance what is the complete sequence farther to the east, details of certain White-Lias beds obtained at Charton Bay have been included.

The marls classed as "Tea-green and Grey Marls" were very carefully measured, and total 75 ft. 6 in. I have grouped the "Grey" and "Tea-green Marls" together because up to the present time there is no palæontological evidence that any portion of the "Grey Marls" is of "Rhætic" age. Mr. H. B. Woodward assigns a thickness of 30 ft. to the "Grey Marls"—"the passage beds from Rhætic into Keuper." He obviously drew his line of demarcation between the "Tea-green" and "Grey Marls" at the base of my Bed 4. In the "Tea-green" and "Grey Marls" are some pinkish bands reminiscent of similar strata occupying the same stratigraphical position in Glamorganshire.

As already mentioned, the dark-coloured marls appear to be unfossiliferous. Mr. Woodward has mentioned this fact, and Mr. A. J. Jukes-Browne has stated that "no fossils have been found in these beds in Devon, but at Watchet, in Somersetshire, *Pecten valoniensis*, *Protocardium rhæticum*, and other fossils of Rhætic species have been recorded from them."

There has been for a long time much debate as to whether these dark-coloured marls should be classed with the Rhætic or with the Keuper. Some authors have held that the occurrence of dark-coloured matter indicated that when the beds were formed Rhætic conditions had been initiated, and, therefore, that they should be regarded as forming an integral portion of the Rhætic Series. No doubt the evidence does tend in this direction; they are, in fact, "passage-beds." But where natural

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* Egerton, *Proc. Geol. Soc.*, vol. iii (1841), p. 409; De la Beche's "Report Geol. Cornwall, etc.," p. 223.

† *Quart. Journ. Geol. Soc.*, vol. xvi (1860), p. 385.

‡ *Proc. Geol. Assoc.*, vol. xvi (1899), pp. 134-136; see also A. J. Jukes-Browne, *Quart. Journ. Geol. Soc.*, vol. lviii (1902), pp. 281-282.

§ *Mem. Geol. Survey*, "The Geology of the Country near Sidmouth and Lyme Regis (1906), pp. 15-17.

causes do not effect a well-defined line of demarcation, for convenience it is necessary to accept a more or less arbitrary one. None can be better than that indicating the downward extension of characteristic Rhætic fossils. At Culverhole it is admitted that no Rhætic fossils have been found in the dark-coloured marls. Then they should not be classed with the Rhætic. On the other hand, at Sully, in Glamorganshire, and again on the opposite side of the estuary in the Watchet district, below the Rhætic Black Shales, and forming the top part of Etheridge's "Grey Marls," are beds containing Rhætic fossils. Therefore they should be grouped with the Rhætic, and correlated with the downward extension of the fossils should be the line of demarcation between Keuper and Rhætic. For mapping purposes, as elsewhere stated,* I support the conclusion arrived at by the officers of the Geological Survey during their work in Glamorganshire, namely, that the line should be drawn at the base of the Black Shales and at the top of the marls. It then indicates a change in the lithic structure of the rocks.

These fossiliferous marls, the Sully Beds, have not been identified on palæontological evidence at Culverhole. The dark-coloured marls here are probably comparable with a similar deposit *below* the Sully Beds in the Watchet district. Mere colour alone, of course, is no proof of contemporaneity, as Dr. G. T. Moody's valuable and very interesting researches on the variegation of the Keuper rocks sufficiently demonstrates†; but the similarity between the deposits (thought to be contemporaneous) in this respect, taken in conjunction with the negative palæontological evidence and stratigraphical position, is suggestive.

After the formation of the black marls of the Culverhole district it may be that there was an uplift of the sea-floor, and that the marls were subjected to subaërial denudation while the Sully Beds were being deposited in the Watchet-Sully area. The eroded surface of the marls at Culverhole was not submerged until the time of the formation of the main Rhætic Bone-bed. At Watchet, however, deposition proceeded almost uninterruptedly, but Lilstock (Little Stoke, *auctt.*) is the only locality in this country that I know of where the *complete* sequence from the Keuper to the Rhætic can be studied. At Culverhole, between the Bone-bed (which fills in fissures in the "Grey Marls"), and the "Grey Marls" there is a gap, a non-sequence. Exactly how much deposit is wanting is a little difficult to say, but probably it does not fall far short of 60 ft.

At Culverhole the Rhætic Series is divisible into three substages—the *Pteria-contorta* Black Shales, the "Upper Rhætic" of my former papers, and the White Lias, the Sully Beds being absent. The unfortunate, although I venture to think excusable,

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* *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 414.
† *Ibid.*, vol. lxi (1905), pp. 431-439.

misapplication of the principal Rhætic terms, such as "Tea-green" and "Grey Marls," Upper Rhætic and White Lias, requires them, in order to prevent any misconception in the future, to be very carefully used.

The thickness of the *Avicula (Pteria)-contorta* Beds at Culverhole is 16 ft. 10 in. Mr. Woodward reckoned it at 18 ft., but this was thought to be an under-estimate by Mr. Jukes-Browne, who suggested that there might have been an error owing to the "White Lias" having slipped forward and obscured the top portion of the Black Shales, *Avicula (Pteria)-contorta* Beds. Fortunately, however, I have been able to examine all the beds of the Upper Rhætic, and to study their passage into the White Lias, and have come to the conclusion that even Mr. Woodward's estimate is too great by over a foot. Near Lyme Regis, according to the deep boring so fortunately recorded by Mr. Jukes-Browne, the Black Shales certainly appear to have increased in thickness—32 ft. is considered to be their probable thickness there.

When I visited Culverhole in June, 1905, and in the same month of this year, it was possible to examine the actual junction of the marls with the Black Shales, but then, owing to landslips, the sequence was interrupted. The next bed, in ascending order, which could be examined was that distinguished as 11 in the record of the section accompanying this paper. It is not very difficult to see that the stratum numbered 6 in Dr. Wright's section is my Bed 11, and accordingly the thickness of the deposit intervening between it and the Bone-bed can be given on his authority.

The Bone-Bed is not usually a compact bed, but occurs as indurated gritty black shale, full of fish-remains and in places filling up fissures in the marl.[*]

As already stated, at the times of my visits it was not possible to examine the whole of the *Avicula (Pteria)-contorta* Beds, but while on the west side of the little cove about three feet of shale was visible above the Bone-Bed, on the east side black shales were just showing below a massive limestone-bed (11), which was on a level with the beach. The shales below this bed were uncommonly fossiliferous and the fossils well preserved.

Correlation of the component beds of the *Avicula (Pteria)-contorta* Beds is frequently a matter of much difficulty. Sufficiently distinctive, permanent, and successive developmental characters have not been made out as yet in any group of Rhætic Mollusca in the beds in this country. Consequently, for minute correlations not a great deal of assistance can be obtained

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[*] In the Street Museum (near Glastonbury) there is a piece of Bone-bed said to have come from "Axmouth," crowded with fish remains, and in all respects similar to that which has been called the "thin" portion (lower) of the Bone-bed in the Lilliput railway cutting near Chipping Sodbury. When the Geologists' Association visited Culverhole in 1899 a number of vertebrate-remains, which were not observed by me, were obtained. These have been added in square brackets to my list.

from this source. On the other hand, however, one or more of the hard bands in the *Avicula* (*Pteria*)-*contorta* Beds are often very persistent, and their identity, at the several localities ***within a certain area*** is comparatively easy to see. Such beds assist materially in the work of correlation, but such stratigraphical evidence must of course be employed very judiciously. In the present case, Bed 9 resembles a stratum which was exposed in the railway-cutting at Charlton Mackarell, near Somerton, Somerset; this again a limestone in the railway-cutting at Dunball, near Puriton (Somerset); the latter a bed occupying the same stratigraphical position (and similar as regards lithological structure) at Lilstock and St. Andries slip, near Watchet; which in turn may be correlated with Bed 9 in the Lavernock-Penarth coast-section. Hence Bed 9 at Culverhole is probably contemporaneous with a similarly notated bed in the Penarth district.

The Upper Rhætic is 5 ft. 9 ins. thick at Culverhole; 14 ft. 6 ins. at Garden Cliff, near Westbury-on-Severn, Gloucestershire. The *Pseudomonotis*-Bed at Garden Cliff is represented in the Wickwar district by typical Cotham marble, frequently full of *Pseudomonotis fallax.*[*] At Culverhole this limestone is, as a rule, of "false Cotham" nature and unmistakable. Occasionally it possesses the typical aborescent markings of the Bristol "Landscape Stone" (Cotham Marble). Overlying the Cotham Marble at Culverhole is a deposit of very tough brown and black clay, which I have noticed also occurs above that bed throughout Somerset. Below the Cotham Marble are greenish-grey marly shales, having at the base a deposit of quartz grains. Near the top of Bed 2 Ostracoda are abundant.

Now the Cotham Marble succeeds beds containing Ostracoda at Lilliput, near Chipping Sodbury; Redland, Bristol; Sedbury Cliff, near Chepstow; and Blue Anchor, near Watchet. Below Bed 2 should come the *Estheria*-Bed. At Garden, Wainlode, Sedbury, and Aust Cliffs, and several other localities, a certain development of the *Estheria*-Bed is of a pale-greenish tint with rudely aborescent markings. Such a bed is present at Culverhole in its proper stratigraphical position, and has been mistaken for the Cotham Marble.[†] Where this bed is well developed at Culverhole the fissile argillaceous limestone above it is very thin, and sometimes, but very rarely, not represented at all. But this is exceptional. As a rule the *Estheria*-Bed, with its aborescent markings occurs at the base of the deposit of fissile argillaceous limestone, and is present only as a thin, irregular bed.

I believe the *Estheria*-Bed of Garden Cliff, with its imperfect aborescent markings, has also been mistaken for the Cotham

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[*] *Geol. Mag.*, 1904, p. 535.

[†] *Mem. Geol. Survey*, "The Geology of the Country near Sidmouth and Lyme Regis 1906), p. 16.

Marble. There is some excuse for the mistake there because the equivalent of the Cotham Marble, the *Pseudomonotis*-Bed, is non-aborescently marked. But no such mistake can be made at Sedbury, Aust, or Culverhole, where both beds are definitely developed.

Immediately above the typical development of the *Estheria*-Bed at Culverhole there is, as a rule, as already mentioned, some fissile argillaceous limestone, which is best associated with the *Estheria*-limestone. This grouping is supported by the fact that the deposit of quartz-grains at the base of Bed 2 corresponds to a similar, but more compact, deposit on the same stratigraphical horizon of Sedbury Cliff.

Marls, indurated in the lower portion and containing a few thin sandstone-layers and an impersistent band of yellowish-green nodular limestone complete the Upper Rhætic division. Beds corresponding to the Upper Rhætic of the Garden Cliff section are therefore neither absent from the Culverhole section, nor are they replaced by "White Lias."

Above the Upper Rhætic at Garden Cliff come the *Ostrea*-Beds of the Lower Lias. A short distance to the east of Culverhole these are parted from the Upper Rhætic deposits by the White Lias, which is said to be about 25 ft. thick. At Culverhole only certain of the basement-beds of the White Lias were examined; the top-beds having been removed by the pre-Cretaceous denudation. The former were very interesting on account of their irregular and much bored upper surfaces, to which oysters were adherent in places.

Even at Charton and Pinhay Bays, where the White Lias is so well developed, there are abundant signs of slow deposition and pene-contemporaneous erosions. Thus some idea may be formed of the time-interval between the depositions of the Cotham Marble and Paper Shales (Liassic) which are in contact at certain localities—Goldcliff, for example.*

About a mile and a-half farther along the coast is Charton Bay.

Charton Bay.—Here the Rhætic Black Shales are much obscured, but the "Tea-green and Grey Marls" are exposed, and there is also an excellent section of the greater portion of the White Lias. This latter is situated to the east of the keeper's cottage, and is in the cliff-side below the road leading down to the beach. Details are given in the table facing this page. The basement-beds were not visible, but since at Pinhay Bay the total thickness of this division is said to be almost 25 ft., and here what could be seen of it measured 19 ft., it may be presumed that there is about 6 ft. unexposed to view. The basal White Lias strata visible at Culverhole measure 2 ft. 10 in. Deducting this from the supposed thickness of the invisible portion of that

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* *Quart. Journ. Geol. Soc.*, vol. lxi (1905), p. 376.

tic.
torta Beds.

	Shales, brown, earthy; selenite	0	4	[illegible] and [illegible] spp.
5b-7	Limestone, dark-grey, earthy, with ½ in.-layer of "beef" on top	1	0	*Pecten* (*Chlamys*) *valoniensis.*
8	Shales, black, imperfectly laminated at the base, better laminated above; very selenitic. Thin sandstone-layer at 8 in. below 5b-7: max. 4 ft. 6 in., average	3	9	Shell-fragments.
	"Beef," with *Avicula* (*Pteria*) *contorta*, very common on top	0	1	
	Shales, black, laminated, earthy	0	2	
9	Limestone, pale-grey, with a slight green tinge, rather			

substage at Charton, the gap appears to be 3 ft. 2 in.[*] Bed 2 of the Lower Lias in lithological structure resembles the White Lias limestones, but since it is intimately connected with the Lower Lias at Pinhay Bay it is best grouped with that stage.

Pinhay[†] *Bay.*—From Lyme Regis this section is reached either along the shore at low water, or by following a tortuous path, amid great masses of slipped chalk and indurated Selbornian Sands, which runs above the first and at the foot of the second cliff, the shore being reached by a flight of rudely fashioned steps. These steps are near a fault which has let down the Lower-Lias limestones on the west, throwing them into juxtaposition with the White Lias. Eastwards are seen the White Lias beds dipping in the same direction and covered by a thick mass of Liassic limestones.

This section was noticed many years ago by De la Beche,[‡] but has received considerable attention from others since.[§] The most interesting feature about it is that although the White Lias attains a considerable thickness, about 25 ft. it is said, there are unmistakable signs of slow deposition and pene-contemporaneous erosions. Certain of the component beds are wedge-shaped (with their thin ends directed eastwards) and occasionally are ripple-marked. The more persistent strata are thin layers of hard limestone with a conchoidal fracture, and it is from the destruction of such limestones as these, I think, that the psephoid bodies were mainly derived. Sir Archibald Geikie has suggested[||] that the calcareous mud may have been exposed to the sun's rays from time to time during the formation of these beds, so that films of mud might have curled up, and these, if subsequently rolled by an incoming tide, would be shaped into "pebble-like concretions."

Certain of the Lower-Lias strata exposed in the quarries at Uplyme much resemble the limestones of the White Lias, so much so indeed that Dr. T. Wright thought they were part of the "White Lias." Since *Ammonites Johnstoni* was amongst the few fossils they contained, he was led to believe that the "White Lias" belonged to the *Planorbis*-Zone.[¶] Four years later, however, he discovered his error, and admitted that "the series included light-coloured limestones belonging to two distinct zones of life.[**] The upper portion he considered to belong to the *Planorbis*-Zone, the lower to the *Avicula-contorta* beds, "or infralias" of some Continental authors, as no true Lias fossil shells were found in it.

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[*] See *Proc. Geol. Assoc.*, vol. xi (1889), p. xliii; *Mem. Geol. Survey*, "The Geology of the Country near Sidmouth and Lyme Regis" (1906), pp.17-18.

[†] Or Pinney.

[‡] Address *Geol. Soc.*, 1848.

[§] *Proc. Geol. Assoc.*, vol. xix, pt. 9 (1906), pp. 337, 338.

[||] *Proc. Geol. Soc.*, vol. xi, Pt. 5 (1889), p. xxx.

[¶] *Quart. Journ. Geol. Soc.*, vol. xvi (1860), p. 396.

[**] *Geol. Mag.* 1864, p. 290; and *Rep. Brit. Assoc.* 1864, Sections, p. 75

Dr. Wright divided the White Lias of this neighbourhood into two parts, and considered the "Anvil-bed" (or "ledge") to be "near the boundary between the under and upper division of the White Lias." The beds below that bed, according to Dr. Wright, "are rubbly beds of limestone, with marly partings and concretionary lands, followed by laminated beds of fine cream-coloured limestone, breaking up into cuboidal fragments when struck with the hammer; below these come nodular masses forming a bed 4 ft. thick, resting upon a band of the 'Landscape Stone,' or true 'Cotham Marble,' 9 in. thick."* He places the thickness of the beds between and inclusive of the "Anvil-bed" and the Cotham Marble at 18 to 20 ft.

Besides being the first to draw attention to the Cotham Marble in this district, Dr. Wright was the first to discover the *Estheria*-Bed, which he described as a "light-coloured concretionary limestone containing *Estheria minuta*." The beds from the Cotham Marble to the Black Shales Dr. Wright examined at Pinhay Bay, following them out "at low ebb during spring-tides."

Deep boring at Lyme Regis.—A deep boring, made in 1901 west of Colway Manor House and about half way between Horn Tavern and Middle Mill Farm, on the left bank of the Lym, showed that the Rhætic was about 63 ft. thick; that is, from the top of the White Lias to the base of the *Pteria-contorta* Shales (*Avicula* (*Pteria*)-*contorta* Beds).† The *Avicula* (*Pteria*)-*contorta* Beds are about twice as thick here as at Culverhole.

Inland there are few natural exposures of the Rhætic. Its probable outcrop in the valleys around Axminster is much obscured by slipped rock.

Axminster and Lyme Regis Branch Railway.—Between Axminster and Lyme Regis are several railway cuttings, in two of which Keuper Marls are seen capped with traces of Rhætic Black Shale. An interesting account of this branch of the London and South-Western Railway has been given by Mr. Woodward.‡ The level-crossing north of Trill has a cutting on each side; in that to the north-west are the "Tea-green and Grey Marls" dipping gently to the south-east. At the south-eastern end higher beds are seen although the dip has lessened, and consist of black shaly marls with pale-coloured marlstones, with—at a short interval—indications of Rhætic Black Shales. In the cutting to the south-east the dip is reversed owing to a synclinal arrangement of the beds, and lower deposits appear. Near Newlands Coppice Mr. Woodward has observed traces of Rhætic Black Shale and White Lias.

Other Exposures in the Neighbourhood of Axminster.—The

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* *Geol. Mag.* 1864, p. 291.

† *Mem. Geol. Surv.*, "The Geology of the Country near Sidmouth and Lyme Regis' (1906), p. 19. *Quart. Journ. Geol. Soc.*, vol. lviii (1902), pp. 279-289.

‡ Summr. Progr. *Geol. Surv. U.K.* 1901 (1902), pp. 53-59.

"Grey Marls" have been observed at Hood, to the north-west of Musbury Castle, and in the valley to the east of the castle.[*] Also at Dane's Hill, Dalwood,[†] and I have seen them in the lane side immediately south of Beckford, on the opposite side of the Valley of the Yarty to Dane's Hill.

The Black Shales have been seen above the "Grey Marls" in the exposures at Dane's Hill and Beckford.

The White Lias has been reached in the large quarry north of Weycroft, and exposed by the railway cutting to the south-west.[‡] About a mile to the north of Axminster, between Greatwood and Chapplecroft Farms, are inlying tracts of beds belonging to this sub-stage. The top bed, the Somerset "Sun-bed," is locally known as the "White Rock,"[§] and according to Mr. C. Reid, F.R.S., exhibits evidence of borings.[‖]

Although just outside the boundary of the district under consideration, it may be mentioned that between the conspicuous Knap Hill and Howley, in the lane to the north of the brook, black clays were noticed, but in the absence of fossils their precise age could not be ascertained.

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[*] *Mem. Geol. Surv.*, "The Geol. Country near Sidmouth and Lyme Regis" (1906), p. 18.

[†] *Idem*. p. 19.

[‡] *Idem*. p. 18.

[§] *Idem*. p. 19.

[‖] *Mem. Geol. Surv.*, "The Jurassic Rocks of Britain," vol. iii (1893), p. 74

THE GEOLOGY OF THE YORKSHIRE COAST BETWEEN REDCAR AND ROBIN HOOD'S BAY.

By R. S. HERRIES, M.A., V.P.G.S., President.

(Read July 7th, 1906. Some advance copies were printed and issued to Members in July. The paper is now reprinted with a few alterations and additions.)

THE custom that the Director of the "Long" Excursion of the Association should write a paper descriptive of the geology of the country to be visited has crystallised into a law, otherwise I should have suggested that the admirable paper by Prof. J. F. Blake,* published in illustration of the last visit of the Association to the Yorkshire Coast, in 1891, should be reprinted and distributed as a pamphlet to the members attending the excursion. Prof. Blake, it is true, deals with "the country between Redcar and Bridlington," whereas my southern limit is Robin Hood's Bay, but I think it will be as well to give a short general sketch of the geology of the Yorkshire Coast as an introduction to that part of it which comprises the exposures of the Lias.

I can only begin by quoting Prof. Blake when he says, "After the abundant work that has been done upon this most interesting area by Phillips, Tate, Hudleston, the Geological Surveyors, Lamplugh, and the writer (Prof. Blake), there is little or nothing original to be said on this district." Since this was written the work of Dr. Rowe† on the Yorkshire Chalk has been published, as well as the *Geological Survey Memoir* by Mr. Fox Strangways,‡ which practically summarises everything that had been written on the subject up to that date.

There have been two previous excursions of the Association to the Yorkshire coast. The first was in 1875, and was directed by Messrs. Hudleston, Woodall, and Fox Strangways, Prof. J. Morris, and Sir C. Strickland. On that occasion Whitby was visited, one night being spent there, and the headquarters were afterwards removed to Scarborough. The second was in 1891, under the guidance of Prof. J. F. Blake, Mr. G. W. Lamplugh, and Rev. E. M. Cole, the party staying first at Driffield and then at Scarborough. On that occasion the whole coast from Bridlington to Whitby was included in the programme, as well as such inland sections as Suffield quarries, Pickering, and Newtondale.

I took part in that excursion, and could not help thinking

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* "The Geology of the Country between Redcar and Bridlington," by J. F. Blake, *Proc. Geol. Assoc.*, vol. xii, p. 115.

† "The Zones of the White Chalk of the English Coast, Part IV, Yorkshire," by A. W. Rowe, *Proc. Geol. Assoc.*, vol. xviii, p. 193.

‡ "The Jurassic Rocks of Britain, vol. i, Yorkshire," by C. Fox Strangways.

that the senior Director, with that superabundance of energy for which he is noted, attempted to get too much into the six days.*

I have therefore decided, and I hope I shall not fall into the opposite extreme, to confine the excursion on this occasion strictly to the coast, and to that part of it which lies to the north of Blea Wyke, where the Dogger first appears from under the sea, so as to embrace the whole of the sections of Lias and the beds immediately overlying it.

There are two excellent reasons for doing this; the first is that at Easter the Association visited the other great coast sections of Lias at Lyme Regis and the neighbourhood, and it will be a great opportunity for those who are able to attend both excursions to compare the two sections. The second reason is that the Association has never visited the district north of Whitby, which can show a succession of cliff sections of a character almost unrivalled in England, culminating in the great cliff of Boulby, 666 ft. in height, said to be the highest in England.

The Yorkshire coast is divided into two distinct parts, of which the northern is rather the larger, by the prominent projection of Flamborough Head, where the chalk Wolds run out to sea. South of this point there is not a scrap of solid geology to be seen, the whole coast of Bridlington Bay being made up of Boulder Clay, sands, and gravels of the Glacial Series. The northern section is again nearly equally divided between the outcrop of the Cretaceous, Neocomian, and Oolitic beds to the south, and the Liassic sections to the north, the dividing point being Blea Wyke just to the south of Robin Hood's Bay. Another peculiarity about this coast may be noted, and that is its unbroken character. Bounded on the north and south by the two great estuaries of the Tees and Humber, it is only breached in its long stretch of upwards of 100 miles by a single river, namely, the Esk, which runs into the sea at Whitby. The cause of this, which was not always the case, will be discussed later.

The geology of Yorkshire, from the Mesozoic period onwards, has so much to distinguish it from other parts of England, that it may fitly be considered as a province apart. The Lias is developed zone by zone in a way that is exceptional, but it does not otherwise present features very different from other parts. Economically it has always been noted, formerly for the alum extracted from the Upper Lias Shales, and for the jet found in the harder beds immediately below, and now for the rich ironstone beds of the Middle Lias. When, however, we come to the Lower Oolites we have a great series of Estuarine beds with certain thin but persistent marine beds separating them into

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* Since these words were written I have received the sad news of the death of Prof. Blake.

Upper, Middle, and Lower. These marine beds all correspond to different horizons of the Inferior Oolite of the south of England, so that when the Cornbrash is found succeeding the Estuarine beds, apparently without a break, it is clear that the Bathonian, if represented at all, must correspond with the Upper Estuarine or part of it. It is true that these Estuarine beds exist in Lincolnshire and the adjoining counties, though they are not so largely developed.

Now when we come to higher beds we find exactly the opposite. While the great deposits of Purbeck and Wealden strata of freshwater or estuarine character were being laid down in the south of England a great marine series was in course of formation in Yorkshire (as well as in Lincolnshire) known as the Speeton Clay, the upper part of which represents also the Lower Greensand of the south. Then again, while the great limestone series of the Bath and Portland Oolites of the south are not represented as such in Yorkshire, the calcareous character of the Coralline Oolite, which all through the Midlands has disappeared, reasserts itself with great strength in Yorkshire, whether as grit, coral rag, or limestone proper.

The absence of Tertiary Beds is not peculiar to Yorkshire, but may be mentioned to complete the contrast with the south of England.

Professor Blake[*] attributes these striking differences to a separation of Yorkshire from the surrounding districts by an axis of elevation which began to be marked in Carboniferous times, running from the Humber to the Tees, and it seems clear that something of this kind must have been the case.

Subjoined is a list of the Cretaceous and Jurassic Rocks as exposed on the Yorkshire coast:

Chalk (without flints).
Chalk (with flints).
Red Chalk (Gault).
Speeton Clay (Neocomian).
Kimeridge Clay.
Upper Limestones
Middle Calcareous Grit
Lower Limestones
Lower Calcareous Grit } Corallian.
Oxford Clay.
Kelloway Rock.
Cornbrash.
Upper Shale and Sandstone (Estuarine) Series.
Grey Oolite, or Scarborough Limestone.
Middle Shale and Sandstone (Estuarine) Series.
Millepore Oolite.

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[*] *Loc. cit.*, p. 117.

Lower Shale and Sandstone (Estuarine) Series (with Ellerbeck Bed).
The Dogger.
Blea Wyke Beds.
Upper Lias (Shales).
Middle Lias (Ironstones and Sandstones).
Lower Lias (Shales).

We will now consider the successive beds in rather more detail, beginning for convenience from the south, that is to say, with the uppermost beds, for there is a general southerly dip, so that as we follow the coast northwards we, generally speaking, pass from newer to older beds.

The *Chalk* first appears on the coast a little north of Bridlington, and forms the cliffs all round Flamborough Head to Speeton. This is the end of the range known as the Wolds, which runs up from the Humber all through South-East Yorkshire till it reaches the sea at this point. As in the south-west of England the chalk overlaps various beds in succession from the Lias upwards. The Chalk ranges from the zone of *Bel. quadratus* to the Lower Chalk which is seen at Speeton.

Below the Lower Chalk comes the *Red Chalk*, which is generally identified with the Gault of the South of England, and below that is the *Speeton Clay*, a thick deposit of blue clay, marine in character and very fossiliferous. The intricate stratigraphy of this deposit has been well worked out in the classic papers of Prof. Judd[*] and Mr. Lamplugh.[†] As I have already stated, it has been classed as Neocomian, and probably represents in time not only the Lower Greensand of the south, but also the Wealden and Purbeck.

It is doubtful whether the Portlandian is represented at all, but the *Kimeridge Clay* crops out below. Very little of this is seen at Speeton, but it should occupy the greater part of Filey Bay, were it not that a mass of Boulder clay entirely fills the space between Speeton and the outcrop of the Corallian near Filey Brig. Occasionally when the foreshore has been swept clear of sand the clay is seen, and the writer was fortunate enough to see a very good exposure in the very wet summer of 1879. This was about a mile north of the Speeton Clay, and was only seen at low water of spring tides, so that the opportunity for observation was short. A considerable thickness of beds, however, was visible as they were dipping at a high angle, and a considerable collection of characteristic fossils was made. Prof. Judd describes a similar exposure (*loc cit.*, p. 238). At different parts of the bay there are large enclosures of blue lias in the Boulder Clay, and it may be that some of these have at times been mistaken for

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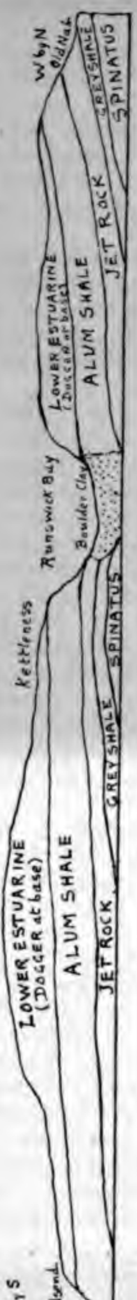
[*] "On the Speeton Clay," *Quart. Journ. Geol. Soc.*. vol. xxiv, p. 218.

[†] "On the Sub-divisions of the Speeton Clay," *Quart. Journ. Geol. Soc.*, vol. xlv, p. 575.


E by S
Staithes
GREY SHALE
SPINATUS & MARGARITATUS
Boulby Cliff
LOWER ESTUARINE
DOGGER
ALUM SHALE
JET ROCK
GREY SHALE
SPINATUS & MARGARITATUS
CAPRICORNUS
JAMESONI
Skinningrove
Boulder Clay
Huntcliff
SPINATUS & MARGARITATUS
CAPRICORNUS
JAMESONI
W by N


E by S
Sandsend
LOWER ESTUARINE (DOGGER at base)
ALUM SHALE
JET ROCK
GREY SHALE
SPINATUS
Kettleness
Runswick Bay
Boulder Clay
LOWER ESTUARINE (DOGGER at base)
ALUM SHALE
JET ROCK
GREY SHALE
SPINATUS
W by N
Old Nab


Baytown
Hawsker
ALUM SHALE
DOGGER
High Whitby
LOWER ESTUARINE
WHITBY
LOWER ESTUARINE
N.W.

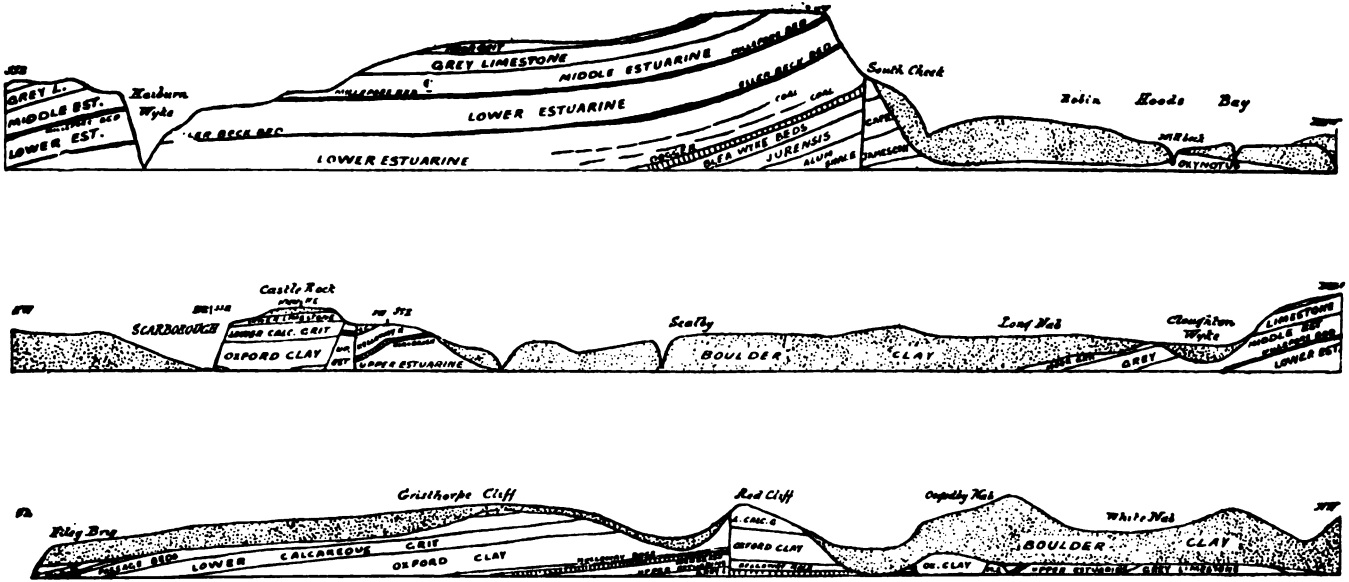


FIG. 1.—SECTION SEEN ALONG THE COAST OF YORKSHIRE FROM HUNTCLIFF TO FILEY BRIG.

(*Huntcliff to Sandsend, by R. S. Herries; Whitby to Filey Brig, by J. F. Blake. Proc. Geol. Assoc*, vol. xii, p. 116.)

N.B.– The apparent dislocation of the strata at Runswick Bay is due to an error in drawing. The lines on the left are drawn too high up, the Jet Rock being very near the shore where cut off by the Boulder Clay. The beds, however, are curiously irregular here. (See p. 433.)

Kimeridge; but one particular mass is so full of fossils from the *Jamesoni* zone of the Lower Lias (perhaps the most unmistakeable of all the Liassic fauna), that it is hardly conceivable that it can have been thought to be Kimeridge.

A little north of Filey the *Corallian* beds rise and run out to sea in the well-known reef of Filey Brig. This series of rocks has been so amply illustrated in the papers by Mr. Hudleston, published in our Proceedings,[*] and by the same author and Prof. J. F. Blake in their well-known monograph in the Geological Society's Journal,[†] that I cannot do better than refer my readers to those papers. Suffice it to say that they divide the beds in descending order into Upper Calcareous Grit, Coral Rag, Upper Limestones, Middle Calcareous Grit, Lower Limestones, and Lower Calcareous Grit. The first two are not seen in the coast sections, the beds that first appear below the Boulder Clay in Filey Bay being the Upper Limestones. The Corallian Beds rise in the cliffs through Gristhorpe Bay, till just beyond Yons Nab, between that bay and Cayton (or Mill) Bay they are brought down again by the considerable fault at Red Cliff, after which they are cut off by Boulder Clay. They are seen at Scarborough Castle Rock, again brought down by a series of faults, which are not easy to understand, but have been carefully worked out and explained by Mr. Hudleston.

Below the Corallian Rocks the *Oxford Clay*, *Kelloway Rock*, and *Cornbrash* rise in succession. On the north side of the Red Cliff fault the Kelloway Rock forms the base of this fine cliff, with the Cornbrash making a reef on the foreshore. The Oxford Clay slopes gently backwards, and is crowned by the Lower Calcareous Grit. These beds again appear at Scarborough Castle.

Below the Cornbrash the great *Estuarine Series* begins, and as these are the first beds which come into the particular district with which we are dealing, they may be described in rather more detail, especially as they and their associated marine beds form a very considerable portion of the cliffs from Scarborough to Whitby. The Estuarine Beds, or "Shales and Sandstones," have been divided into three, Upper, Middle, and Lower. The Upper and Middle are separated by the "Grey Oolite," or Scarborough Limestone, and the Middle and Lower by the "Millepore Oolite." The Lower Shales rest on "The Dogger," and are themselves subdivided by the occurrence of a marine band to which the name of the "Ellerbeck Bed" has been given. The whole series thickens considerably as we go northwards. The *Upper Shales* are first seen in Gristhorpe Bay, where they are not very thick. They occur again in Carnelian Bay, just south of Scarborough,

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[*] "The Yorkshire Oolites, Part II, The Middle Oolites," by W. H. Hudleston," *Proc. Geol. Assoc.*, vol. iv, p. 353, and vol. v, p. 407.

[†] "The Corallian Rocks of England," by Rev. J. F. Blake and W. H. Hudleston, *Quart. Journ. Geol. Soc.*, vol. xxxiii, p. 260.

and they form the cliffs, where not masked by Boulder Clay, from Scalby to Cloughton Wyke, where they leave the shore and continue to form the top of the Staintondale Cliffs nearly as far as the Peak. There is one considerable bed of sandstone known as the Moor Grit and shaly beds, but curiously enough, though vegetable remains are abundant, there are very few recognisable plants, freshwater mussels being practically the only fossils. Very different in this respect are both the Middle and Lower Shales, as in certain bands they both yield a rich harvest of plants (ferns and cycads). The *Middle Series* first occurs at Yons Nab, between Gristhorpe and Cayton Bays, and it is from this locality that most of the plants of this series to be seen in museums have come. The beds are again seen in Cloughton Wyke, whence they continue along the face of the cliffs, getting higher and higher till, like the beds above, they run out at the Peak. These beds consist of sandstones and shales, and towards the base there is, especially at Gristhorpe, a considerable amount of ironstone with marine shells. This seems to be really a continuation upwards of the Millepore Oolite, though generally classed with the Estuarine Beds.

The *Lower Series* is just seen at Gristhorpe below the reefs of Millepore Oolite and again in Carnelian Bay, brought up by the fault at Osgodby Nab, but does not appear again on the coast till just north of Cloughton Wyke, and it occupies the base of the cliffs from there nearly to Blea Wyke Point, where the Dogger rises from the sea. It then rises in the cliff till it is cut off by the Peak fault at the top of the path going down from below the Ravenscar Hotel. It reappears on the high ground inland above the Peak alum quarries, and running round Fylingdales at the back of Robin Hood's Bay it comes to the cliff again near Hawsker Bottoms, beyond which it is brought down by a depression in the Lias nearly to the shore at High Whitby, where the well-known "horsetail" *Equisetum columnare* is found upright in the sandstones as it originally grew. It then rises and continues to form the upper part of the cliff as far as Whitby, about half a mile from which place it is again depressed down to the shore, so that it can be easily worked for ferns, but rises again almost immediately. By the considerable fault at Whitby, along the course of the Esk, it is thrown down so as to form the West Cliff, and it is well seen in the road known as the "Khyber Pass," which has been cut through it. These beds are again seen forming the upper part of the cliffs at Sandsend, nearly as far as Kettleness, and again they cap the huge cliff of Boulby or Rockcliff. These Lower Estuarine Beds consist of shales and sandstones, with occasional seams of coal, nearly six inches thick. The sandstones are much quarried for building stone, and most of the local buildings are built of it, including much of Whitby Abbey. At certain points plant remains are very abundant, and are quite equal in preservation and variety to the better-known plants of Gristhorpe.

We will now deal with the intercalated Marine Bands. The uppermost of these, the *Grey Oolite* or *Scarborough Limestone*, is first seen at Gristhorpe, just above the well-known plant bed. It is somewhat insignificant here, but has developed considerably at its next appearance at White Nab, the south point of Scarborough Bay, having been depressed in the interval by the Red Cliff fault. It is here cut off first by the Boulder Clay which fills the bay, and then by the Scarborough Castle faults, so that it is not again seen till Hundale Point, south of Cloughton Wyke. It there attains a considerable thickness, some 30 ft., and may be very easily studied. For a full description the reader may be referred to Mr. Hudleston's paper on the Lower Oolites of Yorkshire.* It may thence be traced along the face of the Staintondale Cliffs, where it may be examined in places as far as the Peak. Large blocks have fallen from it on the undercliff here, and the fossils may be collected. It appears again in several of the little becks which run down to the cliffs at Hawsker Bottoms between Robin Hood's Bay and Whitby. From fossil evidence, notably the occurrence of *Ammonites Humphresianus* and *A. Blagdeni*, it is fairly certain that this, the highest of the marine beds associated with the Estuarine series, cannot be placed higher than the Inferior Oolite of the South of England, so that, if the Bathonian period is represented here, it must be by the Upper Estuarine Beds, as has already been pointed out.

The next of the Marine Beds is the *Millepore Oolite*, which forms reefs and scars off Yons Point north of Gristhorpe Bay, and like the Grey Oolite it is cut off by the Red Cliff fault. It is next seen brought up by a fault at Osgodby Nab between Cayton and Carnelian Bays. This is a curious section, and there are some Grey Oolite blocks mixed up with the others, but these may be boulders from the Glacial Clay. We do not see the Millepore Beds again till the north side of Cloughton Wyke, where they rise from the sea and form reefs as at Yons Nab. Past Hayburn Wyke and along the Staintondale Cliffs they may be traced till cut off by the Peak fault, and after this they are not seen in the cliff, though they have been recognised like the Grey Oolites in some of the becks north of Robin Hood's Bay. These beds are noted for and named from the abundance of a bryozoa, *Cricopora straminea*, but there are numerous other fossils which are not easily extracted from the peculiar ferruginous matrix. Inland the beds are purely Oolitic, and the fossils are obtained much more easily, as from the Whitwell Quarries in the neighbourhood of Castle Howard. The third Marine Bed, the *Ellerbeck Bed*, does not appear till Hayburn Wyke is reached, and may be traced thence in the cliffs as far as Peak, and can be

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* "The Yorkshire Oolites.—Part I," *Proc. Geol. Assoc.*, vol. iii, p. 283.

seen at intervals wherever the Lower Estuarine Beds are visible, being near the top of the cliff at High Whitby and Boulby. It was first noted as a separate bed by Mr. Barrow,* but it is not of great importance.

Below the Lower Estuarine Beds, and usually resting immediately on the Lias, comes the bed known as "The Dogger," but sometimes called the Inferior Oolite. The latter name should not be used, as it is now recognised that it only represents a part of the Inferior Oolite of the South of England, and so has no exclusive right to that name. This bed first appears a little south of Blea Wyke, and is seen above the Lias wherever the top of that formation is shown. Like the beds above it, it is cut off by the Peak fault, and reappears on the moor 200 ft. or so above the cliff.† It is in the effect on the Dogger and the beds immediately below that this fault exhibits its great peculiarity. The fault runs nearly north and south, with a downthrow to the east of about 400 ft.‡ The beds on the east or downthrow side (which may be spoken of as the south relatively to the place at which it cuts the cliff) are developed to a remarkable extent. Here we have 33 ft. of Dogger, 70 ft. of passage beds known as the Blea Wyke beds, and about 80 ft. of the uppermost zone of the Lias, the *Jurensis* or *Striatulus* beds, whereas on the upthrow side all these beds are absent except about 3 ft. of the Dogger, and are not again seen, though the Dogger thickens somewhat to the north, and passage beds seem again to occur in the neighbourhood of Boulby Cliff. But the fault as it now appears is of more recent date than the deposition of these passage beds, as it dislocates the whole of the Estuarine series and the intercalated marine beds. At first sight, therefore, the fault can have nothing to do with the non-deposition or subsequent erosion (if deposited) of the *Striatulus* and Blea Wyke beds on the south side. It is obvious, however, that it cannot be a mere coincidence that this great change should take place exactly at this point, that there should be a series of beds some 180 ft. thick on one side of the fault, and nothing except a poor attenuated 3 ft. of one of them on the other. There is also a change in character, as the fossils which are so abundant on the south, though occurring mostly in certain lines, are very scarce on the north side, though farther north, between Sandsend and Kettleness, they again become numerous. The true solution, as Mr. Hudleston§ long ago pointed out, must be that the movement indicated by the present fault must have taken place along

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* "On a new Marine Bed in the Lower Oolites of East Yorkshire," *Geol. Mag.*, Dec. 2 vol. iv, p. 552.

† The cliff here referred to is at the point where the path goes down, nearly on the line of the fault, some 200 feet lower than the Peak itself.

‡ This figure is an average. The amount of the downthrow, of course, varies according to whether it is measured from the beds above or below the series of beds intercalated on the south side.

§ *Proc. Geol. Assoc.*, vol. iii, p. 304.

an old line of fracture. We know, especially from recent researches, that this is often the case, and subsequent writers on the subject have taken the same view, *e.g.*, Prof. Blake* and more recently Mr. R. H. Rastall.† Assuming, however, that this was an old line of weakness, the difficulties are not at an end. We have still to account for the fact that the change took place exactly on the line of the fault. Mr. Hudleston (*loc. cit.*, p. 304) says: "It can hardly be supposed that, the distance [between the Peak alum quarries and Blea Wyke] being short of a mile and a quarter, this is due to non-deposition. It really looks as if the bed of the Liassic sea was lifted on the upthrow side of the great fault, and thus brought under the influence of denuding currents, or that the downthrow side sank so as to be preserved from such action." Professor Blake (*loc. cit.*, p. 125) says: "Two interpretations seem possible: one is that the Dogger of Whitby represents only the upper part of the Dogger of the Peak, and the intervening beds are wanting. This involves, first, the existence of the fault at Peak before the Dogger was deposited, which might very well be the case if we suppose it to have formed a line of weakness which again gave way at a later period, and, secondly, an unconformity between the Dogger and the Alum Shale at Whitby. Such an unconformity would be difficult to observe directly with a bed of clay below, but we may well wonder why the denudation has been so uniform that so little, if any, of the *jurensis* beds and lower part of the Inferior Oolite is anywhere left. . . . The other explanation is that the line of the Peak fault marks also the boundary of two regions, distinct in Upper Liassic times, so that the lacking beds were never deposited on the north. To the aid of this hypothesis comes the fact that, while the Liassic Beds have uniformly thinned in going south, all the deposits of the Inferior Oolite thin in going north, and we know nothing of what the Lias does below. Against it is the problem of how the boundary comes to be so very sharp. Still worse, if the deposits were really continuous, then the thin band of the Dogger at Whitby would represent not only the lower beds of the Inferior Oolite, but also the *jurensis* beds. This would make the latter a part of the Dogger series, against which palæontology, as I read it, speaks loudly. Probably a combination of the two views may best suit the case. I think there is some slight unconformity where the Dogger lies directly on the Alum Shale. There is probably also a thin representative of the *jurensis* beds in many spots where it has not yet been definitely proved by palæontology. Their greatest development was probably in the south, and the difference at the Peak may have been somewhat accentuated by a fault."

Mr. Rastall (*loc. cit.*, p. 457) says: "After the deposition of the Lias there was a period of slow elevation which caused the

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* *Proc. Geol. Assoc.*, vol. xii, p. 115.

† "The Blea Wyke Beds and the Dogger in North-East Yorkshire," by R. H. Rastall, *Quart. Journ. Geol. Soc.*, vol. lxi, p. 441.

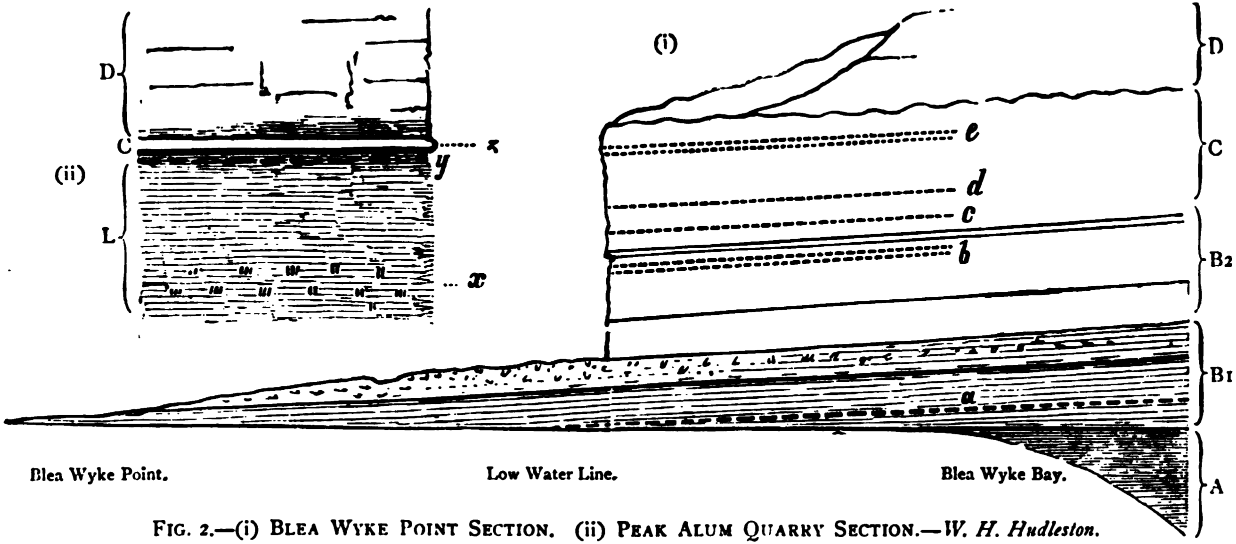

FIG. 2.—(i) BLEA WYKE POINT SECTION. (ii) PEAK ALUM QUARRY SECTION.—*W. H. Hudleston.* [*Proc. Geol. Assoc.*, vol. iii, p. 294].

EXPLANATION OF (i).

A. *Jurensis* zone, top part. The little bay is hollowed out of these beds.

B. Blea Wyke Beds, consisting of: B1. Grey Sands, which, together with the *Serpula* Bed forming the top of the Scar, measure about 26 ft. This sub-division constitutes the platform on which it is possible to walk at low water; the beds have a south-east dip, and the *Serpula* Bed forms a low escarpment from the Scar. B2. Yellow Sands, 25 ft.

C. The Dogger, 33 ft.

D. The Lower Shale and Sandstone.

a. Main *Lingula* Bed. *b. Terebratula* Bed. *c.* Lower Nodule Bed. *d.* Upper Nodule Bed. *e. Nerinæa* Bed.

EXPLANATION OF (ii), REPRESENTING CONTACT OF OOLITE AND LIAS IN PEAK ALUM QUARRY, AND SHOWING RAPID THINNING OF BEDS WITHIN HALF A MILE.

L. Alum Shale of Upper Lias.
x. Leda ovum Bed. *y.* Line of Clay Ironstone Nodules.

C. Dogger, 3 ft., with *z*, Nodule Bed, at its base.
D. Lower Shale and Sandstone.

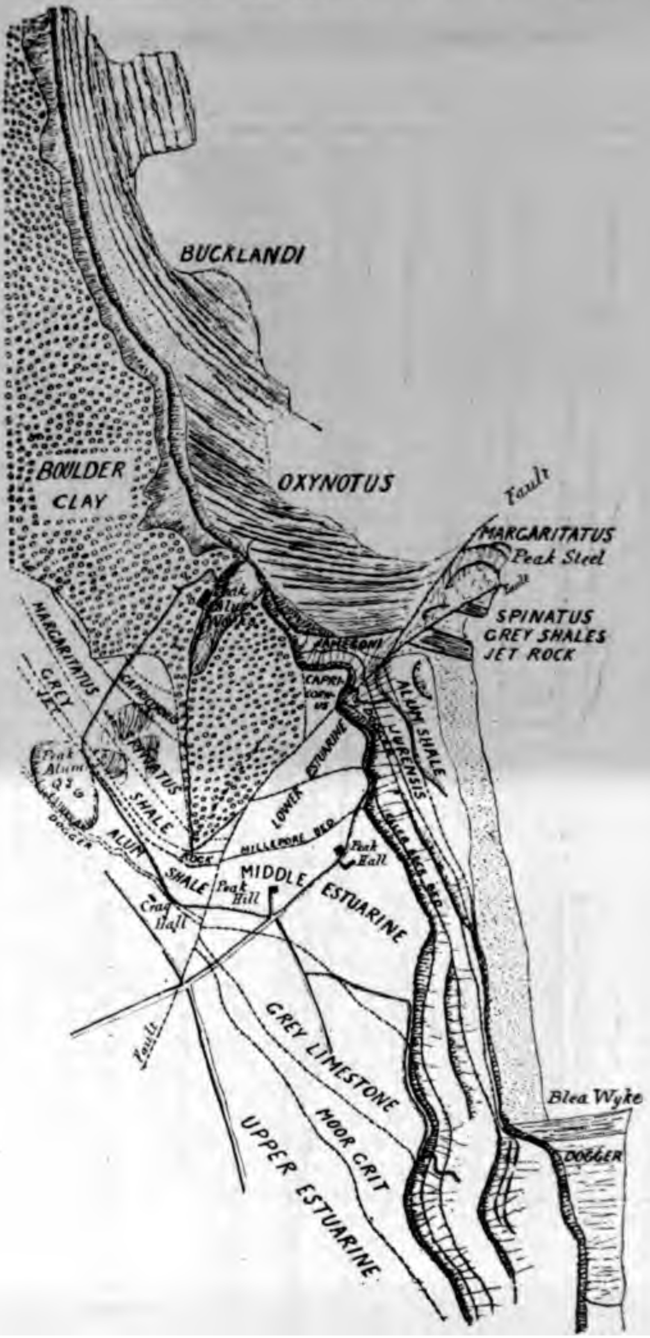

FIG. 3.—SKETCH MAP OF ROCKS BETWEEN BLEA WYKE AND ROBIN HOOD'S BAY.—*J. F. Blake.*

[*Proc. Geol. Assoc.*, vol. xii, p. 119.]

newly-formed strata to be uplifted within reach of wave- and current-action. But it appears that the northern half of the district was more elevated than the southern, and that as first suggested by Mr. Hudleston in 1873 the Peak Fault is partly of pre-Oolitic date. This fault formed a submarine cliff, and in the still water at its foot the Blea Wyke beds were laid down. Eventually the upward movement ceased, the hollow below the fault-scarp was filled up, and the Dogger proper was laid down as a continuous bed over the whole area."

This theory, though very plausible, is difficult to accept, knowing the character of the Lias clays, and how unlikely they would be to admit of the formation of a submarine cliff at a period shortly after their deposition. We should in such a case get many *remanié* fossils from the cliff in the Blea Wyke beds, but though we have numerous pebbles, mostly phosphatic, and mostly in certain definite lines, with occasional fragments of fossils, they do not seem to have been derived from the waste of the neighbouring beds. On the other hand the pebbles found at the base of the Dogger, north of the fault, contain many fragments of Ammonites and other fossils, such as *Trigonia literata*, etc. It has generally been assumed that these fragments are from the Lower Lias, but I think they are probably from the waste of *Striatulus* beds, etc., which formerly existed, but were denuded before the deposition of the Dogger, when these beds were being elevated above the surface. Some of the Ammonite fragments closely resemble *A. striatulus*, and the *Trigonia* already mentioned is characteristic of the upper part of the Alum Shale and of the lower part of the *Striatulus* beds. I think the true explanation is somewhat as follows: Deposition was continuous to the end of the Alum Shale, and while the lower part of the *Striatulus* beds was being laid down. The latter beds show evidence of shallower water conditions, and it is probable that the estuary which afterwards discharged so much sand and clay over this area was already beginning to be effective. Shoals began to be formed, and parts of the sea bottom became dry. Meanwhile a line of weakness developed, due, perhaps to the same causes which were bringing about the changed conditions. On one side of this line there was a slow sinking with which a corresponding slow deposition kept pace, for there is no sign of any rapidity of deposition in the *Striatulus* beds. On the contrary, plenty of time is required for the development of a new series of fossils. At the end of the *Striatulus* period the conditions again changed, the sinking ceased, and the deposition was much more rapid, as evidenced by the character of the Blea Wyke beds. Meanwhile the shoals and land on the other side of the line of weakness had been subject to erosion, and practically all traces of whatever *Striatulus* beds had been deposited were denuded away, as well as part of the Alum Shale, which was left with an uneven surface in places. When the two sides of the fault were on a level, depression began again, and the deposition all over the area was continuous once more, while that part of the Dogger was being deposited which immediately underlies the Lower Estuarine Beds. This would not have happened simultaneously in all places, and this fact accounts for the fossils of the Dogger being found in some places and not in others. Thus at Sandsend and Glaisdale we have not only the usual fossils but even the large terebratulas, which occur at Blea Wyke in the Yellow Sands. The conditions changed rapidly at the last, which would account for the marine life being suddenly killed off as suggested by Professor Blake in accounting for the *Nerinæa* bed (*loc. cit.*, p. 128).

The *Dogger* at Blea Wyke consists of about 33 ft. of ferruginous sandstones of a brownish colour. In the lower part are two distinct lines of pebbles or phosphatic nodules, and about 10 ft. from the top is an extremely fossiliferous band about 1 ft. 6 in. thick, generally called the *Nerinæa* bed, from the abundance of the fine *Nerinæa cingenda* in it. If a good surface of this bed is exposed a collection of a great variety of fossils can be made, all in an excellent state of preservation. The upper 10 ft. of the beds seem to be almost entirely devoid of fossil remains, the fauna having been probably killed off, in accordance with the above-mentioned suggestion of Professor Blake. The Dogger, as has been said, reappears much attenuated in the Peak alum quarries, but is not seen again in the cliff till Hawsker Bottoms, north of which point it continues in the face of the cliff till it comes right down to the shore between Whitby and Saltwick. It then rises again to be again depressed below the sea level by the Whitby fault. After the long interval of Boulder Clay the Dogger appears again overlying the Alum Shale in the Sandsend alum quarries, and continues in the cliff, or a little behind it, as far as Kettleness, after which not much is seen of it till the lofty cliff of Boulby is reached, and at Huntcliff it reappears in the Beacon, half a mile inland, but not in the cliff itself. At Boulby it may be very easily examined in the old Loftus alum quarries on the west side of the headland, and in the Boulby quarries on the east. At the former it is very well developed and highly fossiliferous, and there is much more of the appearance of a passage from the Lias to the Oolites than in any other place along the coast except Blea Wyke. The beds are, however, very variable. Messrs. Tate and Blake* give sections both in the Boulby and Loftus pits to show the changes that take place in little over a mile. Mr. Rastall (*loc. cit.*, p. 451) also gives sections in the Boulby quarries, and a figure illustrating a local erosion of the Upper Lias and Dogger, attention to which has also been drawn by the officers of the Geological Survey.†

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* "The Yorkshire Lias," p. 26.

† "Memoir on the Jurassic Rocks of Britain," vol. i, Yorkshire, by C. Fox Strangways, p. 163.

He does not allude to the fossiliferous beds in the Loftus quarries, and states that in this neighbourhood the most striking feature is the very uneven line of demarcation between the Lias and the Oolites, giving clear evidence of contemporaneous erosion and unconformity. That there are such evidences is locally true, but the erosion is merely of a contemporaneous character and does not support the first statement made by Mr. Rastall unless by uneven line he means doubtful line. In fact, at the Loftus pit the difficulty is to know where the line between the Lias and the Oolites is to be drawn, so gradually do the beds pass into each other and so much do the fossils of the two formations intermingle. Messrs. Tate and Blake confessed to this difficulty, and thought for convenience the line might be drawn at a point some 5 ft. below a bed in which undoubted Liassic fossils admittedly occur. At any rate the pebble bed does not seem to mark the junction.

The following measurements were made by Mr. W. H. Herries and myself at the east end of the Loftus Alum Quarries in 1888 :—

	ft.	in.
Sandy Shales.		
Coaly Shales.		
1. Sandy Shales	7	2
2. Red dogger band	0	2
3. Shale.	1	7
4. Red dogger band — very full of fossils of ordinary *Dogger* type	0	3
5. Shale with irregular doggers mostly near the top, which sometimes form a line . .	1	6
6. Pebble bed, with belemnites	0	3
7. Strong red dogger	0	5
8. Shale—Ammonites (like *Murchisonæ*) . .	1	0
9. Strong red dogger	0	6
10. Blue Shales with small nodules, with red, hard band about a foot above the base—Belemnites, *Cucullæa*, *Trigonia literata*, *Gresslya*, *Pentacrinus*, and Ammonites (like *Striatulus*)	4	10
11. Sandy and rather irregular dogger—Belemnites	0	4
12. Blue Shale with nodules—Ammonites (like *Murchisonæ*) and Belemnites . . .	4	0
13. Irregular dogger—Belemnites and *Leda* (not *ovum*).		

Beds 6, 7, 8, and 9 combine northwards, and at the north end of the pit are only 7 in.

In this section, our bed 4 undoubtedly must be the same as No. 11 (*loc. cit.*, p. 26) in the section of Messrs. Tate and Blake. Our list of fossils agrees very well with theirs. Probably our bed 10 is the same with their 15, below which they suggest putting the junction, but it will be seen that even below that the ammonites are rather of an oolitic than a liassic type, and it is at any rate possible that we have here a representative of the Blea Wyke Beds, if not of the *Jurensis* zone.

The Dogger, except where more particularly described, generally consists of a bed of ferruginous sandstone 3 or 4 ft. thick, sometimes in two blocks separated by shales. There is generally a layer of pebbles at the base of the principal block, and the junction with the Lias is usually more or less unconformable. Except at certain specified localities, the fossils are scarce and difficult to extract, the exceptions being Blea Wyke, the cliffs between Sandsend and Kettleness, and the Loftus Alum Quarries, and Glaisdale inland.

The *Blea Wyke Beds* have already been mentioned as occurring on the scar about a mile south of the Peak fault. They are seen in the cliff between here and the fault, but are not met with elsewhere. As will be seen by reference to Fig. 2, the beds are divided into two distinct groups, which have been called the Yellow Sands and the Grey Sands. They rest on the *Striatulus* Beds of the Lias, but the junction unfortunately cannot be seen at Blea Wyke, owing to an accumulation of shingle, &c., filling up the little bay. It can, however, be studied in the cliff nearer Peak.

The *Yellow Sands* contain scattered fossils throughout, especially belemnites and fragments of ammonites, and a fair number of gasteropods. There is a rotten band near the base full of casts of fossils, but the chief repository is a bed about a foot from the top, full of the large *Terebratula trilineata*, and known as the *Terebratula* Bed.

The *Grey Sands* are divided lithologically into two distinct beds, the lower of which, known as the *Lingula* Bed, is more argillaceous and softer than the one above known as the *Serpula* Bed. *Lingula Beanii* occurs in both, but is particularly abundant in the lower bed, where it occurs in nodules associated with *Discina reflexa*.

The upper division forms a strong scar or platform just at the foot of Blea Wyke point, and the rough surface is full of hard nests of fossils mostly *Serpula*. There are also many belemnites in these beds and large flat ammonites of more than one species, which I should not venture to name.

These Blea Wyke beds have been the subject of a good deal of controversy. Phillips[*] identified the Grey Sands with the Midford Sands of the south of England, and the beds above he classed with the Inferior Oolite. Dr. Wright[†] placed the *Terebratula* Bed and everything below in the Lias, calling it the *Opalinus*-zone. Mr. Hudleston,[‡] Messrs. Tate and Blake,[§] the

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[*] "Geology of the Yorkshire Coast," 3rd Edition, 1875.

[†] "On the sub-division of the Inferior Oolite in the South of England compared with the equivalent beds of that formation on the Yorkshire Coast," by T. Wright, *Quart. Journ. Geol. Soc.*, vol. xvi, p. 1.

[‡] *Proc. Geol. Assoc.*, vol. iii, p. 283.

[§] "The Yorkshire Lias," chap. 4.

officers of the Geological Survey,* and all subsequent writers have drawn the line between the Oolite and the Lias at the base of the Grey Sands and at the top of the *Striatulus* Beds. Mr. Rastall (*loc. cit.*, p. 445) places the lower 25 ft. or so of the Dogger, that is to say, from the base of the *Nerinæa* Beds downwards into the Blea Wyke Beds, but, apparently by an oversight, he has omitted to give his reasons for doing so. Personally, if I wished to alter the accepted classification, I should be inclined to class the whole of the Yellow Sands with the Dogger, and leave the Grey Sands to be called Blea Wyke or Passage Beds, for the reason that the *Terebratula* Bed is found at other places, and particularly near Sandsend, associated with the Dogger, and if that is placed with the Dogger the rest of the Yellow Sands must follow.

We now come to the *Lias*. This great formation is usually divided into Upper, Middle and Lower Lias, the Upper and Lower being for the most part clays, and the Middle, ironstones, sandstones, and "marlstones." The Lias is now, however, more generally divided into zones, of which certain Ammonites form the indices, and as the boundaries of these zones do not always coincide with lithological changes, some little confusion of terms has been brought about. The division of the Lias into zones was first made by Oppel in 1856, and was applied to this country by Dr. Wright in 1860. In their monograph on the Yorkshire Lias, published in 1876, Messrs. Tate and Blake adopted this system of division, and so far as Yorkshire is concerned, the divisions which they adopted stand to-day as well as they did 30 years ago. Their classification was as follows in descending order, and for convenience I have added the grouping of the Geological Survey:

	Survey.	T. & B.
Zone of *Ammonites jurensis*		UPPER LIAS.
" " *communis*		
" " *serpentinus*		
Zone of *Ammonites annulatus*		MIDDLE LIAS.
" " *spinatus*		
" " *margaritatus*		
" " *capricornus*		
" " *Jamesoni*		
(with sub-zone or region of *A. armatus*)		
Zone of *Ammonites oxynotus*		LOWER LIAS.
" " *Bucklandi*		
" " *angulatus*		
" " *planorbis*		

The grouping into Upper, Middle, and Lower Lias by Messrs. Tate and Blake differed from that previously adopted by largely increasing the thickness of the Middle Lias. They no longer adopted a lithological grouping, but, in comformity with

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* "The Geology of the Country between Whitby and Scarborough." Explanation of Sheet 95 (N.W.), by C. Fox Strangways and G. Barrow.

their system of zones, they also arranged the larger groups according to the principal palæontological changes. They say very truly that the most obvious change in the fauna as you examine the series from below upwards is when the *Armatus* beds set in, and again a considerable break, though not so marked, occurs at the top of the *Annulatus*-zone. The officers of the Geological Survey in mapping the Upper, Middle, and Lower Lias found it necessary to draw their lines in accordance with the lithological differences. Apart from the difficulty of drawing lines on palæontological grounds, in places where there are no sections yielding fossils, there is a practical question, which is that the people, for whose use the maps are supposed to be constructed, do not so much trouble themselves about what life zone their houses or fields may be situated on, as they do whether they are on sand, clay, or limestone, or whether there is a reasonable chance of finding one or other of these lithological divisions if they excavate below the surface soil.

The Survey therefore draw the division between the Upper and Middle Lias above the Ironstone Series, that is to say, at the base of the *Annulatus*-zone, or Grey Shales, as they are often called. The line between the Middle and Lower Lias is drawn at the base of the sandy series, and the former therefore includes the zones of *Am. spinatus*, *Am. margaritatus*, and the upper part, about 30 ft., of the zone of *Am. capricornus*, for it is in this zone that the change from shales to sandstones begins. The line is therefore in the middle of a zone, which may be inconvenient for collectors. There is no reason, however, why the latter should trouble themselves about the divisions of Upper, Middle, and Lower. All they need do is to note the zone in which they are working, and this can in general be ascertained from the fossil contents. I say "in general," because there is a considerable amount of overlapping at the boundaries of the zones, and many of the species pass through several zones. Messrs. Tate and Blake in describing the continuous sections to be found along the coast were obliged to commit themselves as to where one zone began and another ended, and it is of course easy in some cases for subsequent workers to criticise their decisions, but not so easy to establish an alternative line. A particular instance may be mentioned both in the upper and lower limits of the zone of *Am. margaritatus*. It would be quite easy to put rather more of the upper beds into the zone of *Am. spinatus*, while the division adopted by Messrs. Tate and Blake between the zones of *Am. margaritatus* and *capricornus* seems rather arbitrary, making it very difficult to assign fossils collected from fallen blocks to their proper zone. In fact the zone of *Am. margaritatus* in Yorkshire might very well be abolished and the beds divided between the zones immediately above and below, but as it is established in other places it is more convenient to keep it, and this is probably what Messrs. Tate and Blake thought. These, however, are minor details, and it must be remembered that "a zone does not constitute a hard and fast line, to which the characteristic ammonite or whatever fossil may be taken as the type is restricted, but merely implies that that species is more abundant there than elsewhere, and that the other fossils with which it is associated constitute a general assemblage which marks out that particular horizon as sufficiently distinct from the rest of the formation."[*] Except, therefore, in cases where it can be established that a particular fossil, or some variation, does not pass out of a particular zone, and that fossil is present, it must be left to some extent to the judgment of individual collectors, especially in isolated sections, to decide in which zone they are working. As a rule, however, the ammonites used as indices of the zones in Yorkshire are very well chosen, and it will be universally admitted that in the case of the Lias no better fossil than the ammonite could be selected. Other zones or regions could be established, no doubt, but no other genus or family could be taken and made to do duty right through. Belemnites have been used in some formations, *e.g.*, by Mr. Lamplugh for the Speeton Clay, but in the Lias their range is much less restricted than is that of the ammonites, though certain of them might be used to mark regions or sub-zones. Thus the zone of *Am. serpentinus* might be subdivided into a lower region containing *Bel. tripartitus* and an upper with *Bel. tubularis*. Then, again, such a zone as *Am. Jamesoni* might with great exactitude be indicated by *Pinna folium* or *Plicatula spinosa*, both of which fossils are extremely abundant in, and are practically restricted to this zone, including its sub-zone of *Am. armatus*, whereas the index ammonite is confined to the upper part and is not very characteristic except locally. It is, however, much more convenient to adhere to one set of fossils for the indices right through, as otherwise it would be difficult to avoid some confusion and overlapping, though the plan of varying the index fossil seems to answer in the Chalk.

We may now consider the various zones of the Lias in more detail, still in descending order. For complete measured sections of the beds the reader must consult Messrs. Tate and Blake's "Yorkshire Lias" or Mr. Fox Strangways' "Memoir on the Jurassic Rocks of Yorkshire," and we may here refer to Fig. 1, from which it will be seen that there are between the Peak and Saltburn two principal anticlines and a syncline between. The first anticline occupies Robin Hood's Bay, and with the assistance of the Peak fault brings up almost the lowest beds of the Lias nearly as soon as they are first seen on the coast. The second anticline is that between Staithes and Saltburn.[†] This does not

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[*] C. Fox Strangways, "The Jurassic Rocks of Britain, vol. i, Yorkshire," p. 27, and see H. B. Woodward "On Geological Zones," *Proc. Geol. Assoc.*, vol. xii, p. 295.

[†] The apparent depression at Skinningrove, seen in Fig. 1, is caused by the southerly or inward dip of the beds, the lowest of which do not therefore appear in the bay, but only at the points.

bring up such low beds. There is a further anticline (not given in the figure) which brings up beds still lower than those seen at Robin Hood's Bay, and this has its axis a little to the south of Redcar, about five miles north of Saltburn. Beyond this, newer beds are seen on the scars to the north-west, and this is the last appearance of the Lias on the Yorkshire coast.

The zone of *Am. jurensis*, as has already been mentioned, occurs only between Blea Wyke point and the Peak, on the south side of the great fault there. The beds consist of a series of blue somewhat sandy shales with bands of hard, calcareous nodules at intervals. The thickness is about 80 to 90 ft., but owing to the character of the cliff in which they occur, and the occasional and imperfect exposures, it is impossible to get anything like correct measurements. The fossils may be obtained by breaking up the nodules, which are peculiarly hard. There are many species of ammonites, and belemnites are numerous and of several kinds, though rather obscure. It should be noted that the characteristic ammonite is not *jurensis* but *striatulus*, whence the beds are generally called the "Striatulus Beds." The zonal ammonite is, however, said to occur at Blea Wyke, though I have not myself met with it. As I have already stated, it is possible that the zone may be represented to some extent elsewhere, *e.g.*, in the Loftus alum quarries, and some of the *remanié* fragments in the Dogger conglomerate may have come from now denuded portions of these beds.

The zone of *Am. communis*, more generally known as the "Alum Shale," from its former economic value as a source of the manufacture of alum, is well exposed and easily examined both on the coast and in many of the inland valleys, owing to the large, now disused, quarries from which the shale was extracted for the purpose of the industry above-mentioned. The beds first appear under the Striatulus beds on the scars between Blea Wyke and the Peak, and in these upper beds the fossils, such as *Trigonia literata*, are much better preserved than in the somewhat lower bed which is seen on the other side of the fault. By the time the fault is reached the beds have risen into the cliff, and on crossing it we find them some 500 ft. higher up at the Peak alum quarries a little way inland. Robin Hood's Bay forms a dome or anticline, so that when the Alum Shale is next seen on the coast at Hawsker Bottoms it is dipping northwards, and comes gradually lower in the cliff till at Saltwick and Whitby it occupies the foreshore, or scars. At Whitby it is cut off by the fault, and it is next met with in the Sandsend alum pits, and continues in the cliff, where not obscured by Boulder Clay, rising towards the north-west nearly as far as Old Nab, just south of Staithes; after this it is seen in the cliff of Boulby, where, as already stated, it has been extensively worked for alum, both on the east and west sides. After this it is seen no more in the cliffs. The Alum Shale consists of about 90 ft. of blue, somewhat crumbling shales, weathering white, with irregular lines of nodules in the upper part, and certain more continuous dogger* bands which generally occur in the lower part. The alum quarries have been the chief repository of the large saurian remains so well known from Yorkshire. These include besides several species of *Ichthyosaurus* and *Plesiosaurus*, the great crocodile *Teleosaurus Chapmanni*. Parts of the sturgeon, *Gyrosteus mirabilis*, are also met with not uncommonly, though a complete skeleton is, I believe, yet to be found. It is worthy of note that the large Liassic Reptiles of the south of England are found almost exclusively in the Lower Lias, while in Yorkshire, though occasional vertebræ and other bones are found in every zone, the complete skeletons are almost entirely confined to the Alum Shale and Jet Rock. Ammonites and belemnites are very common in the Alum Shale, as is the large *Nautilus astacoides*, but otherwise the fauna is a poor one. The structure known as "cone in cone" is not uncommon in the Alum Shale.

The zone of *Am. serpentinus* is generally referred to as the "Jet Rock," though the name should in strictness be confined to the lower part, as it is only there that that mineral is found.† The beds, like the one above, are easily traced by the old workings. Jet is still sought for, but not to a large extent, the demand having decreased, partly owing to the dictates of fashion, and partly because of the cheap imitations with which the market has been flooded. The occurrences of this bed are almost the same as those of the Alum Shale. It forms the base of the cliff at the Peak fault, and here one can stand and pick out specimens of *Inoceramus dubius* with one hand, and characteristic *Jamesoni*-zone fossils with the other. It has been largely worked at the top of the cliffs north of Robin Hood's Bay, and it is well seen on the foreshore at Hawsker Bottoms and at Saltwick, where it forms the base of Saltwick Nab and the Black Nab, as well as the reefs farther out, which stretch across the bay. It has been worked all along from Sandsend to Runswick, and nearly to Staithes, and is again conspicuous in the upper part of Boulby Cliff. The *Serpentinus*-zone consists of about 90 ft. of hard dark blue shales, which have a peculiar appearance when seen in the cliffs, often turning rather white, though this may be partly caused by wash from the Alum Shale above. There are lines of hard pyritous doggers throughout, but in the lower part, or Jet Rock proper, these are very large and form two or three strong, almost continuous layers, well known as the "Cheese" doggers, above, so called from their shape, and the "animal" or "fish" doggers below, from the frequent occurrence

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* It should be explained that the word "dogger" is used in the sense of a nodule or hard band of rock, as well as in the particular sense of the series called "The Dogger."

† The colour for "Jet Rock" in the Geological Maps is confined to the Jet Rock, proper, and so does not represent the whole of the zone of *Am. serpentinus*.

of vertebrate remains in them. As the alum workings in the zone above, so have the Jet workings in this zone been of assistance in supplying our museums with fine specimens, which are not so easily met with by the ordinary collector.

In the case of the Jet Rock it is the fish remains that are so plentiful, especially the well-known "scale fish," *Lepidotus semiserratus*. The small *Leptolepis saltviciensis* may be collected from the reefs off Saltwick whenever the state of the tide permits. The skeletons of saurians have also been uncovered by the Jet-workers. The ammonites are particularly numerous and interesting, the falciform ammonites or Harpoceratidæ (if that is the present name) being suddenly developed in a remarkable degree. There are also many species of belemnites, among which the curious elongated form of *Bel. tubularis*, with its flattened point, must always attract attention. There are also several species of the allied forms of the cuttle-fish type. Of these *Geoteuthis* is not uncommon in the nodules derived from the Jet Rock between Sandsend and Kettleness. One common fossil should also be noted, generally known as *Trigonellites*. This is of triangular form with well-marked diagonal striations, and it is generally thought to be the aptychus of an ammonite. Of the rest *Inoceramus dubius* is universal and might well mark the zone, as the best line of junction with the beds above and below is made by noting the presence or absence of that shell. In the lower part of the beds *Posidonomya Bronni* is also very characteristic. The occurrence of bitumen in the shales should be noted, causing them when freshly fractured to smell strongly of that mineral, which often in liquid form fills the chambers of ammonites, and is by some thought to be the origin of the jet.

The zone of *Am. annulatus* is usually spoken of as the "Grey Shales." It first occurs close to the Peak fault on the scars, when, like the other beds, it is cut off and next appears at the top of the cliff at the North Cheek of Robin Hood's Bay, coming down to the shore at Hawsker Bottoms, where it may be well seen. It is next observed on the scar beyond Sandsend at Overdale Wyke, and again on the scars on both sides of Kettleness, rising into the cliff at the point. In Runswick Bay and Rosedale and Brackenberry Wykes it is on the scars, after which it rises in the cliff as far as Staithes, and is seen on the face of Boulby Cliff, and lastly it is found just at the top of Huntcliff. The beds, which are not of much interest, are about 30 ft. thick, and consist of grey crumbling shales. They are marked by the presence of *Am. annulatus*, which generally occurs in a particular band of rather flattened nodules. *Belemnites cylindricus* is also characteristic, though it passes up from the zone below.

The next zone, that of *Am. spinatus*, or the Ironstone series, has entirely replaced the Alum Shale and Jet Rock, as thehorizon of commercial value in the Liassic series in Yorkshire. It is from this zone that the great bulk of the iron ore is derived which supplies the blast furnaces of Cleveland with their material.

This great industry, which dates back little more than fifty years, has completely transformed the district of North Cleveland, and has caused great increase of population and the rise of at least one great town, namely, Middlesbrough, from what was but a small hamlet. For an account of the history of the iron mining in Cleveland the reader may consult Messrs. Tate and Blake's "Yorkshire Lias," chap. xiv, or the chapter on Economic Geology in the *Geological Survey Memoir* on the Jurassic Rocks of Yorkshire, chap. xviii.

The zone is first seen on the south side of the Peak fault, forming the eastern half of the long reef of rocks stretching out to sea, known as Peak Steel. It is faulted against the *Margaritatus* beds which are here wedged in by a fork of the main fault (see Fig. 3). The beds come down from the top of the cliff at the North Cheek with a northerly dip till they run out in scars at Normanby Stye Batts, under Hawsker Bottoms. They next appear from under the Grey Shales at Kettleness, where they occupy the scars and the base of the cliff. On the west side of the point the beds are depressed below the Grey Shales, but come up and form the scars again, passing once more below the Grey Shales about the middle of Runswick Bay. They next come to the surface in Brackenberry Wyke, and form the headland of Old Nab, just east of Staithes, beyond which place they rise in the cliff, though obscured by Boulder Clay, till Boulby is reached, where they are about half-way up. Just before reaching Hummersea there is a fine exposure of the edges of these beds on the scar, caused by a great slip from the cliffs above. Every bed can here be easily measured. In place they form the upper part of the Hummersea cliff, and occupy a similar position at Huntcliff. The *Spinatus* beds consist generally of grey, sandy shales, with lines of ferruginous doggers which vary very much in thickness. At Hawsker the lines of doggers are only a few inches thick, but they increase towards the north and north-west, till at Eston, near Middlesbrough, the "main seam" of ironstone is 11 ft. thick, besides which there are the "Pecten" seam, 4 ft. 6 in., and the "Two-foot" seam, 2 ft. 1 in. At Kettleness the main seam is in two blocks, 1 ft. 9 in. and 1 ft. 6 in., while at Staithes the blocks are 3 ft. and 2 ft. 2 in. At the great slip near Hummersea the main seam is 8 ft. 9 in., of which 1 ft. in the middle is shaly, and the Pecten seam is 3 ft. 6 in., of which about half is shale, and the "Two-foot" seam is 1 ft. 3 in. The total thickness of the beds, according to Messrs. Tate and Blake, is from 30 to 40 ft., but the officers of the Geological Survey would include rather more beds in this zone, which Messrs. Tate and Blake had put into the *Margaritatus*-zone. They would give a thickness to the zone of 50 to 60 ft. The fossils in the Ironstone series are very numerous and interesting, and very many species of gasteropods have been obtained by the careful researches of Messrs. Tate and Blake. The nodules both at Hawsker and Kettleness yield large numbers of fossils on being broken up.

FIG. 4.—PLAN OF SEA SHORE FROM HAWSKER TO ROBIN HOOD'S BAY.—*J. F. Blake.*
[*Proc. Geol. Assoc., vol xii, p.* 123.]

The zone of *Am. margaritatus*, or "Marlstone" series, is, as already explained, very closely bound up with the Ironstone series, though the lower half might well be united with the upper part of the *Capricornus* beds below. It appears first on the scar at Peak Steel both in the fork of the faults (see Fig. 3) and on the south side faulted against itself. On the other side of the anticline it comes down to the shore at Castle Chamber, just beyond the North Cheek of Robin Hood's Bay, and occupies the foreshore of the little bay till the *Spinatus* beds come down near Hawsker Bottoms (see Fig. 4). We do not see these beds again till a little east of Staithes, when they appear on the shore and ascend into the cliff. They are seen in the face of Boulby and Hummersea cliffs, and again at Huntcliff, where they supply a large number of the huge fallen blocks, which form such a feature at the base of the cliffs. The only other exposure is in the farthest reef off Coatham, where the beds are not easily accessible. nor are they in a condition for study.

The *Margaritatus* beds are divisible into an upper shaly and a lower sandy series. The whole averages from 90 to 110 ft., according to where you take the uppermost limit. The upper series consists of sandy shales with ironstone doggers, of which one, which is taken as the highest bed of the zone, is of economic value, and is known as the "Avicula" seam. The lower division is about 50 ft. thick and is made up of sandstones and indurated sandy shales, all more or less calcareous. The fossils are numerous, and some of them such as *Cardium truncatum* and *Dentalium giganteum* occur in extraordinary profusion. It may be noted that these beds are generally correlated with the sandy beds at Golden Cap, in Dorset, known as the "Three tiers" with the

Starfish bed above. Starfish occur in the fallen blocks under Huntcliff and Boulby, some of which appear to have come from the *Margaritatus* beds, but the chief habitat of the starfish in Yorkshire is the zone next below.

The zone of *Am. capricornus* is first seen in the cliff at Peak, faulted against the Lower Estuarine Beds and Dogger. On the other side of the anticline it forms the upper part of the cliff stretching from Robin Hood's Bay Town to the North Cheek, before which point it has come down to the shore and forms the scar as far as Castle Chamber (see Fig. 4). It does not rise again above the sea level till Staithes is reached, where it forms the lower part of Colburn Nab, and the scars nearly as far as Boulby Cliff, where it rises in the cliff to come down at Hummersea, of which cliff it forms the lower 50 ft. or so. On the other side of Skinningrove it rises again in the face of Huntcliff, beyond which it is masked by the Boulder Clay. Afterwards it is only seen on the Coatham scars, where it cannot be favourably examined. These beds, like those immediately above, are divisible into two lithological groups, the upper of which consists of calcareous sandy beds of the same character as those at the bottom of the overlying zone. In these sandy beds most of the starfish are found at Staithes and in fallen blocks at Robin Hood's Bay, Boulby, and Huntcliff. They are also marked by oyster beds (*Gryphæa cymbium*), and there is one layer at Castle Chamber which is a mass of *Dentalium giganteum*. The beds below are grey sandy shales with lines of red doggers, many of which contain the zonal ammonite, and one particular layer near the base of the series always contains *Am. fimbriatus*. The thickness of the beds is generally from 120 to 140 ft., of which the upper 30 ft. or so belong to the sandy series. They are generally correlated with the "Green Ammonite Beds" of the Dorset section. Besides the starfish and other echinodermata (*Cidaris* and *Pentacrinus*) the fossils are not of special interest.

The occurrence of the zone of *Am. Jamesoni* is almost exactly the same as that of *Am. capricornus*. It is first seen on the upthrow side of the Peak fault, where at the base of the cliff it is contiguous to the beds of the *Serpentinus*-zone. It forms the cliff on which Bay Town is built, and the scars opposite the town passing under the beds of the zone above before the North Cheek is reached. It is next brought partly up by a low anticline, first under Boulby and then under Huntcliff, and is last seen forming the innermost reef of the Coatham Scars. The beds of this zone consist of a series of micaceous shales and red doggers. The thickness at Robin Hood's Bay is about 200 ft., of which the lower 90 ft. are reckoned by Messrs. Tate and Blake as belonging to the sub-zone of *Am. armatus*. These lower beds are extremely rich in fossils, which often occur in pyritous nests. The fossils are of very great interest, especially the ammonites and belemnites, which latter are very abundant. *Pinna folium*, *Plicatula spinosa*, *Chemnitzia Blainvillei*, and *Spiriferina Walcotti* are very characteristic. Drift wood is particularly abundant in these beds. This zone is unmistakeably the same as the "Belemnite Beds" of Dorset, well seen under Golden Cap.

The zone of *Am. oxynotus* is beautifully exposed at Robin Hood's Bay, on the scars of which the beds stretch in a sort of semi-circle from Bay Town to Peak Steel, where they are cut off by the fault (see Fig. 5). They rise in the cliff near the old alum works and come down again near Mill Beck. The thickness is about 100 ft., and the beds consist of blue and grey shales often much indurated, separated by strong calcareous layers. The only other exposure on the coast is in a reef between the Redcar and Coatham Scars known as High Stones. The *Oxynotus* Beds are sometimes sub-divided into the zones of *Am. raricostatus*, *Am. oxynotus*, and *Am. obtusus* in descending order, and these subdivisions hold good fairly well at Robin Hood's Bay. The fossils in these beds are numerous, and there is a great variety of ammonites. Belemnites, are, however, scarce. In Dorset the "Black Marl" corresponds to this zone.

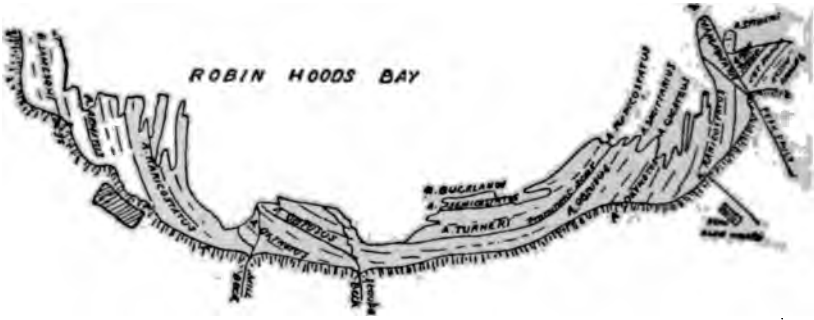

FIG. 5.—SHORE-PLAN IN ROBIN HOOD'S BAY, SHOWING THE POSITION OF THE LIAS ZONES.—*G. Barrow.*

[“*Explications des Excursions*,” Cong. Géol. Int., 1888, p. 138]

The zone of *Am. Bucklandi* forms the most seaward of the scars at Robin Hood's Bay in two portions, one between Mill and Stoupe Becks, and the other farther to the south towards the Peak. The strike of these two exposures does not quite agree; probably there is a small fault along the line of Stoupe Beck. The beds, which consist of alternations of limestones and shales, are about 30 ft. thick, only the upper part of the zone being represented. The only other exposures of the *Bucklandi* beds are at and near Redcar. Here they are exposed at low water in a series of flat scars coming out underneath the sands which stretch from Redcar to Saltburn. There are the same alternations of shales and limestones, but the thickness is about 180 ft. The beds are extremely fossiliferous; *Pleurotomaria anglica* and other gasteropods, corals, very large ammonites, *Gryphæa arcuata*, *Cardinia Listeri* are commonly met with. These beds dip to the north-west. About two miles farther east, in Marske Bay, beds are sometimes exposed, the fossils in which show that they belong to the *Bucklandi*-zone, dipping to the south-east, showing that in the Redcar and Coatham Scars we are dealing with an anticline. The *Bucklandi* beds are seen in Dorset in the Church Cliffs at Lyme Regis.

The zone of *Am. angulatus* is only exposed on the coast at Redcar in the scars nearest the shore. It dips under the *Bucklandi* beds, and forms the lowest visible bed of the anticline, though it is possible that if the sand of the beach were all removed lower beds still might be seen. About 30 ft. of beds are seen consisting of blue shales and limestones alternating. The fossils are interesting, and the general facies is similar to that of the zone above.

The zone of *Am. planorbis* does not occur on the coast in Yorkshire. Blocks of limestone containing the index Ammonite, or one very closely allied to it, are washed up from time to time along the coast, or are found in the Boulder Clay. The best sections of these beds inland are at North Cliff, near Market Weighton, in the East Riding, where the *Angulatus* beds may also be well studied.

A word must now be said about one other great series of deposits which fill a considerable place in our district. I mean the Glacial Drifts. These were first divided by Messrs. Wood and Rome* into Hessle Clay, Purple Clay, and Basement Clay, and subsequently by Mr. Lamplugh† into an Upper and Lower Boulder Clay, with an intermediate bed of stratified clays, sands, and gravels. Probably all are more or less represented in our area, though Mr. Lamplugh's paper only deals with the neighbourhood of Flamborough.

There is hardly a bay along the coast in which the glacial beds are not seen. As I mentioned at the beginning of this paper, the whole coast south of Flamborough, known as Bridlington Bay, is composed of glacial beds. We find them also in Filey, Cayton, and Scarborough (north and south) Bays, the bays north of Scalby, Robin Hood's Bay, Dunsley Bay to the west of Whitby, Runswick Bay, the bay between Staithes and Boulby, Skinningrove, and Marske Bay. There is therefore ample opportunity for their study. They consist of red and brown very tough clays, full of boulders of all sorts and sizes, often well polished and with well-marked striæ, and intercalated layers of sand and gravel. They often weather into curious craggy forms owing to the fur-

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* "On the Glacial and Postglacial Structure of Lincolnshire and South-east Yorkshire," *Quart. Journ. Geol. Soc.*, vol. xxiv, p. 146.

† "On the Drifts of Flamborough Head," *Quart. Journ. Geol.* Soc., vol. xlvii, p. 384.

rowing of the rain-water on their bare surfaces, as may be seen in Filey Bay. The boulders vary from the great masses of Lias in Filey Bay to the smallest stones. Instances of scratched rock surfaces preserved under these clays are rare. One was noticed by Mr. Lamplugh* on the surface of the Upper Limestone neor Filey Point, in which the direction of the striæ was north 20 deg. east.

A study of the boulders will soon convince anyone that the movement was from the north. The great masses of Lias are mostly found in Filey Bay, south of the outcrop of these beds. Farther north we find blocks of Permian or Carboniferous Limestone. There are also a number of igneous rocks, amongst others the easily recognisable Shap granite. A careful record of the boulders has been lately compiled by the Yorkshire geologists.† It is generally supposed that the glacier or ice sheet descended the valley of the Tees from the west, and then turned south along the coast, finding its way into all the old valleys as it advanced and plugging them up. Whether it was forced to do this by being met by a stronger sheet advancing from Scandinavia, as is thought by some, it is not necessary to give an opinion. This is treading on very delicate ground, and the arguments for and against are each as convincing as are those of the physicist and geologist about the age of the earth. Whatever the cause the result has brought about the peculiar circumstance which I have already mentioned, namely the practical absence of rivers all along the Yorkshire coast. Even the one exception, the Esk, has had to cut itself a gorge to escape out to sea, its natural outlet into Dunsley Bay having been blocked by the Boulder Clay. The drainage of a large area both of the Moors and the Tabular Hills, the waters of which now join the Derwent and escape through the gorge at Kirkham Abbey to flow southwards into the Ouse close to its junction with the Humber, would naturally have flowed the other way down the vale of Pickering into the sea in Filey Bay. The great mass of clay which was forced into Filey Bay had the curious effect of turning the river back on its course, so that it now flows up the valley, which it would naturally flow down. In the same way the upper Derwent, which would have flowed into the sea at Scalby, was forced to cut through the Forge Valley gorge into the Vale of Pickering. The bottoms of these old pre-glacial valleys are often below the present sea level, indicating that the land has been depressed since that time. If the "Raised Beach" at Saltburn is really one, there must have been some rise of the coast since then, but so far as I know there is no other evidence of raised beaches in the district, the shell bed in the Speeton Cliffs being, according to Mr. Lam-

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* "On the larger Boulders of Flamborough Head and other parts of the Yorkshire Coast," by G. W. Lamplugh, *Proc. Yorks. Geol.* and *Poly. Soc.*, vol. ix, p. 340, and vol. xi, pp. 231 and 397. Prof. Kendall in his paper cited below p. 494 mentions five other cases of striation.

† Reports of East Riding Boulder Committee in the "Transactions of the Hull Geological Society."

plugh, an inclusion of older date in the glacial clays.* This alteration in level of the land must be taken into account in considering the height above sea level to which the barrier of Boulder Clay reached at the mouths of the valleys in glacial time, which is a factor in Prof. Kendall's theory mentioned below.

For further particulars I must refer the reader to the papers of Mr. Lamplugh already quoted, and no one who is interested in the subject should omit to read the interesting and suggestive paper by Prof. P. F. Kendall† on the system of lakes which he believes to have existed in glacial times in the inland district just west of our area.

It will only be in the contents of the glacial clays that those interested in igneous rocks will have any opportunity of collecting specimens on the official excursions. It should, however, be mentioned that the great Cleveland Basaltic Dyke, which traverses the country for miles in a nearly straight line with a direction almost W.N.W. and E.S.E. from the Tees valley to the moors at the back of Robin Hood's Bay, may be easily visited from Whitby. It is largely quarried for road metal, locally called Whinstone, in the neighbourhood of Goathland and Egton Bridge.

We have now followed the beds as they appear, and described them in some detail, and it only remains to say a few words about the sections themselves. It would be difficult to find a more magnificent set of cliffs than those stretching from a few miles south of Robin Hood's Bay to Saltburn. At their feet there are, as a rule, flat platforms of rock or shale as the case may be, uncovered at low water, locally known as scars. These are good examples on a small scale of "planes of marine denudation."

The first sections to be visited will be the Whitby East Cliff and Saltwick. Here the Alum Shale and Jet Rock can be studied as well as the overlying Dogger and Lower Estuarine Beds. The promontory of Saltwick Nab and the island of Black Nab probably owe their peculiar shapes to having been quarried for alum.

The second and third days will be devoted to Robin Hood's Bay and the cliffs immediately to the north and south, that is to say from Blea Wyke to Hawsker Bottoms. There are few more striking bits of marine scenery than Robin Hood's Bay. Whether you look at the fine, nearly vertical cliffs of Hawsker and the North Cheek or the grand headland of Peak, or whether you stand on the top of that cliff and see the reefs sweeping round on the foreshore in their graceful curves, and the old town itself, perched on the dark blue rocks of the *Jamesoni* Beds, it is all equally pleasing to the eye. To the geologist it is a paradise, for besides having the little set of unique passage beds preserved at Blea Wyke, the whole of the Yorkshire Lias except the two lowest zones may here be studied

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* *Quart. Journ. Geol. Soc.*, vol. xlvii, p. 429.

† "A System of Glacier Lakes in the Cleveland Hills," *Quart. Journ. Geol. Soc.*, vol. lviii, p. 471.

without any difficulty. In the middle, on the scars (see Fig. 5), are the *Oxynotus* and *Bucklandi* beds, on either side the *Jamesoni* beds, followed on the north side by the higher beds in succession, the *Capricornus*, *Margaritatus*, *Spinatus*, and *Annulatus* zones, each of which may be studied bed by bed on the scars as far as Hawsker (see Fig. 4). On the south side the *Capricornus* beds are only visible in the cliff, but the others may be seen beyond the fault on the scars, as well as all the beds of the Upper Lias including the *Jurensis*-zone.

The fourth day the cliffs from Sandsend to Kettleness will be seen, which, if not quite so striking as those of Hawsker, are yet very fine. The Upper Lias is well seen, and the ironstone of the *Spinatus* beds appears at Kettleness. Beyond is the pretty little bay of Runswick, with its village, a cluster of red-roofed houses seeming to cling to the sides of the steep cliff.

The two last days will include the coast from Staithes to Saltburn, with the two grand cliffs of Boulby and Huntcliff. The latter is perhaps the most impressive, though not much more than half the height. Both stand on a base of *Jamesoni* beds, but while at Huntcliff the highest beds are those of the *Spinatus*-zone, at Boulby we have all the Upper Lias and Dogger and a considerable part of the Lower Estuarine series as well. This cliff is not vertical, but has a fine bold outline, especially when seen from the east. Staithes is another picturesque little fishing town situated in the deep gorge cut through the Middle Lias by the little beck which here finds its way to the sea. Saltburn is a rising watering place, and is situated on the Boulder Clay which stretches away to Redcar, with five miles of beautiful firm sand at its foot. These sands are always to be found where there are Boulder Clay cliffs, *e.g.*, Filey, Dunsley (Whitby) Bay, Runswick, etc.

As to the fossils, those of the Lias have been exhaustively dealt with by Messrs. Tate and Blake, and much has been written by Mr. Hudleston, especially on those of the Lower Oolite, so that there is not much to say. Full lists will be found in the *Geological Survey Memoir* of the Jurassic Rocks. I therefore only append a list of those which may be likely to be found on the excursion. I may say that I have used the term ammonite, not because I do not think that it should be split up into families and genera, but because in the present state of nomenclature a prudent man, who is not a specialist, will do well to steer clear of the pitfalls surrounding the use of almost any of the new names, and take his stand on the firm ground provided by the old name of ammonite. The ammonites and belemnites present a problem to which no solution has, so far as I know, been found. How does it happen that they both come on in such abundance and so highly developed? One set of ammonites does not seem to be deduced in any way from another, but each new family comes on, as it were, in perfection. Where did they come from, and where did they mature? The belemnites, too, are quite a feature of the Lias. They do not, however, come into great prominence till the *Jamesoni* beds. Among them there is more appearance of devolution, but our knowledge of specific (or generic?) values of the belemnites is at present somewhat vague. The gasteropods, after reaching a maximum in the *Spinatus* beds, nearly die out altogether in the Upper Lias, to be revived again under new conditions with the commencement of the Oolites. I have already alluded to the Reptiles of the Alum Shale and Jet Rock, and the Fishes of the latter. For a detailed account of the Fishes the reader should consult a series of papers by Dr. Smith Woodward* in the Proceedings of the Yorkshire Geological and Polytechnic Society, as well as in our own PROCEEDINGS. The jet rock fossils may be obtained from the fallen nodules in the cliffs at Hawsker, and north of Sandsend. It is always worth while to search the fallen blocks of *Margaritatus* and *Capricornus* sandstones, especially under Huntcliff, Boulby, and the North Cheek of Robin Hood's Bay. Starfish of several species, *Cidaris* (test and spines), and many other rare fossils, may thus be found, and the same may be said of the blocks of *Jamesoni* beds, especially under Peak, where I have found the test of more than one Echinus, and a large *Ophioderma*, besides many other fossils. The *Oxynotus* and *Bucklandi* scars at Robin Hood's Bay require careful searching, and the lines of fossiliferous nodules require to be known, a remark which applies to other zones as well. For the common fossils the reader may refer to the list below.

I will now bring this somewhat rambling paper to an end, and express a hope that this excursion may be the means of inducing many of those who attend to become, in the concluding words of the classical work of Messrs. Tate and Blake, "out-door students of THE YORKSHIRE LIAS."

N.B.—While these pages were passing through the press, came the sad intelligence of the death of Prof. J. F. Blake, one of the authors so often quoted, and the leader of the last excursion to Yorkshire in 1891, when he was filling the chair of the Association. I take this opportunity of placing on record my deep debt of gratitude for the teaching derived from him through the work for which he was jointly responsible with Prof. Tate. When my brother, Mr. W. H. Herries, and I first began, as boys, seriously to collect from the Lias of Yorkshire in 1876, we were fortunate enough to have a copy of "The Yorkshire Lias," then just published, placed in our hands. We, therefore, from the first, collected in accordance with the zonal divisions established by Messrs. Tate and Blake, which may, perhaps, add

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* "Fossil Fishes of the Upper Lias of Whitby," *Proc. Yorks. Geol. and Poly. Soc.*, vol. xiii, pp. 25, 155, 325, 455, and see *Proc. Geol. Assoc.*, vol. xi, p. 32.

a certain value to the collections we made. I had hoped, when this excursion was first planned, to have had the assistance and advice of Professor Blake in carrying it out, but I had been aware for some time that the state of his health would render that impossible. But it comes as something like a shock that he should be taken from us on the very eve of the repetition of the excursion, which he had led so ably and enthusiastically on the last occasion, thus leaving it to other hands to try to do what he, had he been in health, would have done so well, and with an intimate knowledge of the sections such as few other people can have had.

LIST OF FOSSILS LIKELY TO BE MET WITH.

THE DOGGER.

Natica cincta.
,, adducta.
Chemnitzia lineata.
Cerithium Beanii.
,, muricatum.
,, vetustum.
Nerinæa cingenda.
Alaria Phillipsii.
,, unicarinata.
Onustus pyramidatus.
Nerita pseudocostata.
Neritopsis lævigata.
Turbo lævigatus.
Delphinula funiculata.
,, granata.
Actæon Sedgvici.
Turritella quadrivittata.
Gervillia tortuosa.
,, lata.
Pteroperna striata.
Modiola cuneata.
Trigonia denticulata.
,, V-costata.
,, spinulosa.
Astarte elegans.
Opis Phillipsii.
Ceromya Bajociana.
Gresslya adducta.
Rhynchonella obsoleta.

THE BLEA WYKE BEDS.

Ammonites aalensis.
,, comensis.
Belemnites Bucklandi.
,, aalensis.
,, inornatus.
,, irregularis.
,, Milleri.
Cerithium muricatum.
,, vetustum.
Turritella quadrivittata.
Monotis substriatus.
,, inæquivalvis.
Gervillia Hartmanni.
Pinna cuneata.
Gresslya peregrina.
Pholadomya fidicula.
Trigonia Leckenbyi.
Rhynchonella cynocephala.
Terebratula trilineata.
Discina reflexa.
Lingula Beanii.
Eryma Birdii.
Serpula deplexa.
Vermicularia compressa.

Zone of AM. JURENSIS.

Ammonites striatulus.
,, compactilis.
,, variabilis.
Belemnites lævis.
,, subaduncatus.
,, dorsalis.
,, Voltzii.
,, latesulcatus.
Actæonina pulla.
Cerithium armatum.
Monotis substriatus.
,, inæquivalvis.
Trigonia literata.
Gresslya donaciformis.

Zone of AM. COMMUNIS.

Teleosaurus Chapmanni
Ichthyosaurus } *various.*
Plesiosaurus }
Gyrosteus mirabilis.
Nautilus astacoides.
Ammonites communis.
,, Holandrei.
,, crassus.
,, subarmatus.
,, fibulatus.
,, bifrons.
,, heterophyllus.
,, ovatus (primordialis).
,, elegans.
Belemnites vulgaris.
,, levidensis.
,, lævis.
,, Voltzii.
,, subaduncatus.
,, subtenuis.
,, striolatus.
,, dorsalis.
,, breviformis.
Cerithium quadrilineatum.
Monotis substriatus.
Inoceramus cinctus.
Trigonia literata.
Gresslya donaciformis.
Leda ovum.
Discina reflexa.
Lingula longoviciensis.
Eryon Hartmanni.

Zone of AM. SERPENTINUS.

Lepidotus semiserratus.
Leptolepis saltviciensis.
Ammonites serpentinus.
,, elegans.

Ammonites Lythensis.
„ exaratus.
„ gracilis.
„ heterophyllus.
„ cornucopia.
Belemnites lævis.
„ tubularis.
„ crossotelus.
„ tripartitus.
„ inæquistriatus.
„ subaduncatus.
„ striolatus.
„ subtenuis.
„ latesulcatus.
„ dorsalis.
„ vulgaris.
„ validus.
„ breviformis.
Geoteuthis coriaceus.
Euomphalus minutus.
Monotis substriatus.
Inoceramus dubius.
Posidonomya Bronni.
Extracrinus britannicus.

Zone of AM. ANNULATUS.

Ammonites annulatus.
„ semicelatus.
Belemnites cylindricus.
Cerithium liassicum.
Monotis inæquivalvis.
Astarte striatosulcata.
Gresslya intermedia.
Leda galathea.

Zone of AM. SPINATUS.

Ammonites spinatus.
„ margaritatus.
„ ferrugineus.
Belemnites breviformis.
„ vulgaris.
„ cylindricus.
„ rudis.
„ apicicurvatus.
„ clavatus.
Cryptænia expansa.
Eucyclus cingendus.
Chemnitzia Blainvillei.
Cerithium liassicum.
Turbo acicula.
„ cyclostoma.
Pecten æquivalvis.
„ lunularis.
Monotis inæquivalvis.
„ cygnipes.
Modiola scalprum,
Limea acuticosta.
Macrodon intermedius.
Leda galathea.
Cardinia lævis.
Unicardium subglobosum.
Pholadomya ambigua.
Gresslya intermedia.
Pleuromya costata.
Rhynchonella tetrahedra.
„ lineata.
Terebratula punctata.
Chordophyllites cicatricosus.

Zone of AM. MARGARITATUS.

Ammonites margaritatus.
„ spinatus.
Belemnites cylindricus.
„ elongatus.
„ apicicurvatus.
„ Milleri.
„ clavatus.
Eucyclus cingendus.
Chemnitzia Blainvillei.
Dentalium giganteum.
Gryphæa cymbium (*var.* depressa).
Pecten æquivalvis.
„ lunularis.
Lima Hermanni.
Limea acuticosta.
Monotis cygnipes.
„ inæquivalvis.
Leda galathea.
Modiola scalprum.
Protocardium truncatum.
Pholadomya ambigua.
Gresslya intermedia.
Pleuromya costata.
Rhynchonella tetrahedra.
Ophioderma Milleri.
Cidaris Edwardsi.
Pentacrinus gracilis.

Zone of AM. CAPRICORNUS.

Ammonites capricornus.
„ defossus.
„ fimbriatus.
„ Henleyi.
Belemnites elongatus.
„ apicicurvatus.
„ aspergillum.
„ clavatus.
Chemnitzia Blainvillei.
Eucyclus undulatus.
Dentalium giganteum.
Gryphæa cymbium (*var.* depressa).
Pecten æquivalvis.
„ calvus.
„ lunularis.
Lima Hermanni.
Monotis inæquivalvis.
Inoceramus ventricosus.

Modiola scalprum.
Protocardium truncatum.
Pholadomya ambigua.
Pleuromya costata.
Rhynchonella variabilis.
Ophioderma, Milleri.
„ carinata.
Cidaris Edwardsi.
Pentacrinus interbrachiatus.

Zone of AM. JAMESONI.

Ammonites Jamesoni.
„ brevispina.
„ striatus.
„ armatus.
„ trivialis (polymorphus).
Belemnites elegans.
„ virgatus.
„ araris.
„ charmouthensis.
„ clavatus.
Chemnitzia Blainvillei.
Gryphæa cymbium (*var.* obliquata).
Pecten æquivalvis.
„ priscus.
Limea acuticosta.
Plicatula spinosa.
Monotis inæquivalvis.
Pinna folium.
Modiola scalprum.
Leda galathea.
Hippopodium ponderosum.
Protocardium truncatum.
Unicardium cardioides.
Pholadomya decorata.
Spiriferina Walcotti.
Waldheimia sarthacensis.
Rhynchonella tetrahedra.
„ variabilis.
Ditrupa capitata.
Hemipedina *sp.*

Zone of AM. OXYNOTUS.

Ammonites oxynotus.
„ raricostatus.
„ impendens.
„ gagateus.
„ obtusus.
„ sagittarius.
Ammonites stellaris.
„ planicostatus.
„ densinodus.
Nautilus intermedius.
Belemnites acutus.
„ infundibulum.
Gryphæa arcuata.
Pecten priscus.
Monotis inæquivalvis.
Modiola scalprum.
Leda galathea.
Hippopodium ponderosum.
Cardinia Listeri.
Pholadomya ventricosa.
Pentacrinus tuberculatus.
„ basaltiformis.

Zones of AM. BUCKLANDI and AM. ANGULATUS.

Ammonites Bucklandi.
„ angulatus.
„ Conybeari.
„ Birchii.
„ Turneri.
„ Brooki.
„ semicostatus.
Nautilus striatus.
Belemnites acutus.
„ infundibulum.
Cryptænia solarioides.
Pleurotomaria anglica (similis).
Turbo Philemon.
Eucyclus elegans.
Turritella Dunkeri.
Gryphæa arcuata.
Pecten textorius.
Lima gigantea.
„ hettangiensis.
Plicatula liasina.
Modiola hillanoides.
Leda galathea.
Astarte obsoleta.
Cardinia Listeri.
Hippopodium ponderosum.
Lucina limbata.
Pholadomya ventricosa.
Pleuromya liasina.
Montlivaltia Haimei.
„ Guettardi.

ORDINARY MEETING.

FRIDAY, JUNE 8TH, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

THE minutes of previous meeting were read and confirmed.

The following were elected members of the Association: Frank Gossling, M. Davenport Hill, M.A., and Arnold B. Vansittart.

The President then rose and said:

"Before proceeding with the business of the meeting it is fitting that I should say a few words on a subject which is in all our thoughts. I mean the death of Mr. Emary, our late Secretary, who for so many years had regularly attended these meetings and taken part in the business of the evening. It was only in the latter part of April that I heard that Mr. Emary was not well, and that he would probably not be able to get to the meeting held in May, and about ten days later I heard from Mrs. Emary that his was likely to be a long illness. I went to see him on the 11th, and found him very anxious about the affairs of the Association. He expressed a wish to resign his post, in view of the fact that he had been told that it would be necessary for him to be away from work for at least six months, but we little thought that, before the circular in which allusion was made to his illness was in the hands of the members, he would have passed away. The heart failed rapidly at the end, and he died without pain on May 25th. His funeral was attended by several representative members of the Association, myself as President; Dr. Smith Woodward, my immediate predecessor in the chair; Mr. A. C. Young, his co-Secretary; Mr. E. T. Newton, who was President when Mr. Emary was appointed Secretary; Mr. Potter, one of the founders of the Association; and Mr. Kidner, who acted as Secretary to the Committee which was formed for the purpose of presenting Mr. and Mrs. Emary with a gift on their marriage, less than three years ago. A beautiful wreath was placed on the coffin in the name of the Association.

"The loss which the Association has sustained is a great one, and I believe it is the first instance of an executive officer dying during the term of his office. Mr. Emary, though a good geologist, had not the time to give to original work, but he gave his services freely not only to this Association, but to other bodies such as the Birkbeck College, and in that very material way contributed to the advancement of our science. Punctual and precise in his duties as Secretary, his help has been invaluable to successive occupants of this chair and to his brother officers, and his place will not be easy to fill. My own acquaintance with Mr.

Emary dates back some thirteen years, and as I have served on the Council with him during the whole period of his Secretaryship, nearly nine years, I feel that I have indeed lost a friend. Your hearts will, I know, go out to his young widow, and to his parents, for both of whom your sympathy is asked in the resolution I am about to propose."

The President then put the following resolutions (which had already been adopted by the Council):

(1) "That the Council and Members of the Geologists' Association desire to place on record their deep sense of regret at the loss sustained by the Association by the death of their Secretary, Mr. Percy Emary, and their keen appreciation of the work done by him during nearly nine years of office."

(2) "That this resolution be entered on the minutes of the Council and of the Association, and copies sent to Mrs. Emary and to Mr. and Mrs. Emary, sen., with an expression of sincere sympathy with them in their bereavement."

Both resolutions were unanimously agreed to.

Messrs. Ll. Treacher and H. J. Osborne White exhibited a large number of specimens in illustration of their papers.

The following papers were then read: "On the Occurrence of Quartzose Gravel in the Reading Beds, at Lane End (Bucks)," by H. J. Osborne White, F.G.S., and "The Higher Zones of the Upper Chalk in the Western Part of the London Basin," by Ll. Treacher, F.G.S., and H. J. Osborne White, F.G.S.

SPECIAL GENERAL MEETING.

FRIDAY, JULY 6TH, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

On behalf of the Council the President moved the following resolution, of which due notice had been given:

"That in view of the expenditure necessary to maintain the Library in an efficient state, and the small use made of the Library by the members of the Association, it is hereby resolved that the Library be handed over to the authorities at University College on condition that the members of the Association have access in perpetuity to the whole of the Science Library of the College, including that of the Association, with all their present privileges, and that the College authorities undertake to place and maintain the Library of the Association in an efficient condition at their own expense, and to grant access to the Library to members of the Association up to 8 p.m. on meeting nights, of which there will be not more than twelve in the year, the Association on their part undertaking to continue so far as possible the series of exchanges with other societies as at present."

This was seconded by Mr. J. Hopkinson.

Mr. M. A. C. Hinton moved the following amendment:

"That this meeting do stand adjourned until next Session, and that the Council do in the meantime furnish to all members a complete statement of all facts relating to the Library and their proposal to part with it."

This was seconded by Mr. W. H. Davis.

Afrer some discussion Mr. Hinton asked leave to withdraw his amendment, but the seconder objecting

The President put the amendment to the meeting and it was lost, only one member voting in its favour, whereupon

The President put the original motion, which was carried with but one dissentient.

ORDINARY MEETING.

FRIDAY, JULY 6TH, 1906.

R. S. HERRIES, M.A., V.P.G.S., President, in the Chair.

The President announced that, acting under Rule XIV, the Council had appointed Mr. George W. Young, F.G.S., to be one of the Secretaries of the Association in place of the late Mr. Percy Emary.

The minutes of the last meeting were read and confirmed.

The following were elected members of the Association: Frederick Penny, Miss M. E. Vinter, M.A., B.Sc., and William Dickson Lang, M.A., F.G.S., F.Z.S.

The following papers were read: "The Geology of the Yorkshire Coast between Redcar and Robin Hood's Bay," by the President, and "The Rhætic and contiguous Deposits of Devon and Dorset," by L. Richardson, F.G.S.

EXCURSION TO BATTLE AND NETHERFIELD.

SATURDAY, MAY 19TH, 1906.

Directors: E. J. BAILY AND W. WHITAKER, F.R.S.

Excursion Secretary: ALFRED C. YOUNG.

Report by W. WHITAKER.

ON reaching Battle at 11.15 a.m., a party of 17 drove from the station for some three miles northward, then turning westward to Mountfield and to the office of the Gypsum Works in Millham Wood.

Whilst waiting here some remarks were made on the general geology of the district, and on the deep borings, made for the purpose of scientific exploration, and which had resulted in the finding of a large bed of workable gypsum.

Some cars had been prepared for the use of members by the kindness of Mr. H. W. Kemp, manager of the works (who gave every facility to the Association), and in these they were taken along the Company's railway in the valley through the woods for about a mile W.S.W. to the works, which are in the midst of the woods on the left or northern side of the little River Line.

A plan of the underground gypsum-mine was shown, specimens of the rock were taken from the heaps, and the manufacture of plaster of Paris was explained.

The details of the two great borings of "The Sub-Wealden Exploration" have been printed in various publications, and one need only refer for them to the *Geological Survey Memoir* on "The Water Supply of Sussex" (pp. 65-70).

The Purbeck Beds here come to the surface, and in them the gypsum is found at a depth of over 120 ft., some of the beds being several feet thick.

At the depth of about 170 ft. Portland Beds are reached, and found to be from 105 to 110 ft. thick.

Beneath this formation Kimeridge Clay comes on, and was found to have the extraordinary thickness of not far short of 1,300 ft., its greatest in the kingdom. Corallian Beds continue the downward succession, with a thickness of about 240 ft., and then Oxford Clay, in which the deeper boring ends at the depth of 1,906 ft.

It was pointed out that the object of this exploration was not to find coal, as is often said, but simply to see what rocks occurred at great depth beneath the Purbeck Beds, the lowest geologic division that comes to the surface in the whole Wealden area. Of course there was a hope that at great depth some much older rock might be reached; but the boring has proved what was not known or even suspected before, namely, that here there is a regular normal sequence downward through the Upper well into the Middle Jurassic, both divisions being well represented, as far as the boring has gone.

After thanking Mr. Kemp for all his kind favours the party walked westward to a large quarry by the western end of Counsellor's Wood, and a little south-eastward of Darvell Beech, which is worked for road-metal. Here there are alternations of clay, stone and shells, and many fish-remains have been found.

There was here some discussion as to whether the Geological Survey was right in mapping these beds with the Purbecks, or whether they might not be a faulted mass of Wadhurst Clay. It should be remarked of the various beds of the central Wealden area that one of their characteristics is to be somewhat like each other, whereby classification is sometimes made difficult. A fault that would bring Wadhurst Clay into this position would have to be of considerable throw, and to accept the Wadhurst view would need much more evidence than some likeness in the beds to what may be seen in the Wadhurst Clay elsewhere.

Walking to Netherfield the party again took to the carriages and drove into Battle, and saw Mr. Baily's fine collection of local fossils found in the Wadhurst Clay and Purbeck Beds. These fossils have all been carefully labelled, showing the quarry from whence they came, and comprise over one hundred bones and over two hundred teeth of the extinct dinosauria of the Wealden Formation, including a splendid skull of Goniopholis Simus from the Purbeck Beds.

After viewing the above the party drove to the Black Horse Quarry, Telham Hill, and there saw a somewhat overgrown section of Wadhurst Clay with layers of stone, which latter are now worked for road-metal in bell-pits on the northern side of the old pit. These pits have yielded Mr. Baily many of his best specimens. Thence they walked to Crowhurst village and saw a pit on the northern side of the line about a quarter of a mile W.N.W., showing clay with layers of stone, the latter being thicker in the lower part, the Wadhurst Clay being here again worked for road-metal.

Most of the party then walked southward to the village, saw the old church, with a notably large yew tree in the churchyard, and the remains of the Manor House, returning to the Station Hotel for meat tea, where a hearty vote of thanks was accorded the Directors.

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EXCURSION TO LEWES.

SATURDAY, JUNE 23RD, 1906.

Director: G. E. DIBLEY, F.G.S.*

(*Report by* THE DIRECTOR.)

THE party, numbering seven, arrived at Lewes in glorious midsummer weather, and proceeded to the pits at the eastern end of the town. The first two, locally known as the Navigation Pits, are situated in the *Micraster cor-anguinum*-zone. The dust and heat from the factory prevented the second being visited. At the southern end of the first pit a fine layer of subsequently formed tabular flint was noticed cutting the beds at about 40°.

A few yards farther to the east the celebrated Southerham Pit of Mantell exhibited features of special interest. Upon entering, the *Micraster cor-anguinum* beds revealed the same horizontality as in the former pits, but at about 100 ft. from the Lewes end the chalk dips northwards, which brings the lower beds up at nearly 30°, and thus exposes the whole of the *Holaster planus* and the greater part of the *Terebratulina gracilis*-zones.

A very interesting section in the *Holaster planus* chalk, formerly overgrown with ivy, had been specially cleared for the party through the kindness of the manager, Mr. Weller. This section had been noticed by Mr. Strahan,† and the particular band referred to in the programme consisted of an exceedingly hard layer 1 ft. 6 in. in thickness, very like the Chalk Rock. Overlying this is the band of distinctly phosphatic chalk of Mr. Strahan. Samples were taken, but only one fossil—a fragment of *H. planus*—was discovered. A few hundred yards to the south-east, owing to the rapid dip, a pit was reached revealing Lower Chalk. The Director had observed a large Ammonite the previous evening, but owing to extensive blasting operations just prior to the entrance of the party it had been obscured by the débris. The Director and certain members have much cause to be thankful, for just before leaving the pit an enormous mass of

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* Owing to the unfortunate indisposition of Mr. C. Davies Sherborn, F.G.S., F.Z.S., who had arranged for this excursion, it was undertaken, at his request, by G. E. D.

† "On a Phosphatic Chalk with *Holaster planus* at Lewes," *Quart. Journ. Geol. Soc.*, vol. lii, p. 463.

chalk weighing many hundreds of tons fell where only a very short time previously they had been exploring.

At the southern end of the pit the beds are distinctly observed to dip again to the south, which readily accounts for the position of the beds on the other side of the valley—visited by the Director earlier in the morning—and for the position of the *Marsupite* and *Bel. quadratus*-zones at Seaford, only a few miles distant.

After a short walk and climb, lunch was taken on the edge of a lynchett amid delightful surroundings.

A move was then made to Ranscombe Pit, which is a large excavation of about 200 ft. exposure, situated in the *Rhynchonella cuvieri*, *T. gracilis*, and, in all probability, part of the *H. planus*-zone. Specimens of *Spondylus spinosus*—the flattened form—*Inoceramus cuvieri*, a tooth of *Ptychodus mammillaris*, all indicative of this horizon, and a tooth of *Notidanus microdon* were obtained by the Director.

Evidently the beds near here have been much folded to allow of the exposure of these zones, as the pit visited just before is in Lower Chalk.

Upon leaving this pit, a few yards down the tramway, Mr. Whitaker drew attention to the luxuriant vegetation and somewhat moist character of the soil, which evidently marked the site of the *Actinocamax plena*, March. (The entrance to this pit is through a farmyard on the left side of the Glynde Road.)

The map indicated Lower Chalk at this horizon, which line when carried across the valley brings one to the pits in Lower Chalk. In the Glynde Pit, which was next visited, an interesting oblique seam of weathered pyrites, extending from summit to base in the north-east corner, was pointed out by Mr. Whitaker. A few of the typical fossils of the *Holaster subglobosus*-zone were obtained, comprising *H. subglobosus*, *Pecten beaveri*, a cast of *solarium*, a tooth of *Ptychodus decurrens*; and a large specimen of *Discoidea cylindrica* was given to the Director the previous evening by Miss Wynn, who kindly allowed an inspection of her collection.

After an interval for refreshments the party (a truly enthusiastic one of *veteran* geologists, four of the members being seventy years of age and upwards), proceeded by the path over the downs to Glyndebourne Pit, which consisted of beds—apparently by their lithological character and position—wholly in *R. cuvieri* and *T. gracilis* chalk. Unfortunately no fossils of any zonal value were procured. Several beautiful coombes were passed during the ramble, but at this point the Glynde Bourne is specially noteworthy, the source and course of the bourne being distinctly visible. Time did not permit for a visit to the Malling Pit, which consists of chalk of *H. planus* and *T. gracilis* age as mentioned in the circular.

An exceedingly pleasant walk over the downs by Cliffe Hill to the head of The Coombe and then along the northern slope into Lewes, where tea was served at Messrs. Paravaceni's, brought a very enjoyable day to a close, the members returning by the 8.27 p.m. train.

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Ordnance Maps, 1-inch scale, Nos. 319 and 334.

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1901. JOHNSON.—"Cretaceous Rocks at Glynde and their Fossils," *Geol. Mag.* (4), vol. 8, p. 249.

1903-4. JUKES-BROWNE and HILL.—"Cretaceous Rocks of Britain." *Mem. Geol. Survey*, vol. 2, p. 400; vol. iii, p. 46.

EXCURSION TO SHERE AND ALBURY.

SATURDAY, JUNE 30TH, 1906.

Director: THE PRESIDENT (R. S. HERRIES. M.A., V.P.G.S.).

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTOR.)

THE party left Cannon Street by the 1.2 p.m. train, arriving at Gomshall at 2.34, where it mustered 34. The well-known section of false-bedded Folkestone Sands at the station was first examined, and the little capping of gravel pointed out. The members then walked westwards through Shere to Sherbourn Farm, where there is a chain of ponds just at the foot of the chalk, the uppermost of which is generally known as "The Silent Pool." The Director mentioned that the level of the water in the pool had a year or two ago sunk very low, and this had been locally attributed to the tapping of the chalk for water by the Woking Waterworks authorities on the other side of the escarpment. He did not think, however, that this could be the cause, and the fact that the pool was once more full seemed conclusive on this point. When the Director last visited the pool, about Christmas time, it was full, but the water was very thick and dirty-looking, but it was now quite clear. Mr. Whitaker confirmed the Director's view as to the impossibility of the Woking Waterworks affecting the level of the water in the pool. The level, he said, was no doubt dependent on the variation in the amount of rainfall from time to time. The down was then climbed to a quarry in Upper Chalk, which Mr. G. W. Young, who was present, believed to belong to the lower part of the zone of *Micraster cor-testudinarium.* Some fossils were obtained, and the very fine view over the Greensand and Weald country was admired. Descending again to Sherbourn Farm, the party proceeded a short distance westwards along the road, and (by kind permission of the Duke of Northumberland) entered the brick-yard on the left just under Weston Wood. The clay worked is the Gault, the outcrop of which is very narrow. The section was not in a very good condition for examination, but a few fossils were found, mostly broken. Close by, at the edge of the wood, which occupies high ground, sand pits have been opened in the Folkestone Beds, showing very characteristic sections. The path along the northern edge of the wood was followed, this being a part of the so-called "Pilgrims' Way." There are several large blocks of sarsen stones close to the path. Some speculation was indulged in as to how they got there. Turning south at the end of the wood, and passing some more fine sections of Folkestone Sands, the village of Albury was reached, and the steep lane leading southwards to Blackheath was taken. All the way up there is a continuous section of hard calcareous beds interstratified with more sandy material, the beds having a slight dip to the south, which was due, as the Director explained, to the fact that the section was to the south of the faulted area which marks the Peasemarsh disturbance. About halfway up the Director had on a previous visit found a large tooth, probably derived from the Oolites; and higher up a bed was observed full of fragments of fossils, mostly *exogyra* and *terebratula*. At this point pebbles set in, in several beds, and continue to the top of the lane and spread over the fields higher up on the right. The Director explained that these pebble beds marked the division between the Folkestone and Hythe Beds, or the Upper Ferruginous Beds and Pebble Beds with Bargate of Prof. Gregory. The upper part of the section with *terebratulæ* and the tooth was similar to the Bargate Stone of Guildford and Godalming. Time did not permit of continuing along the lane down the corresponding slope to the south, where the beds which had been seen coming up are all repeated, but the Director drew attention to the fact that after reaching the bottom and crossing the stream these hard calcareous beds of the Hythe series are not again seen, but the ferruginous Folkestone Sands come on as the ascent to Blackheath begins. The slight southerly dip of the Hythe beds did not seem sufficient to take them under the sands of Blackheath, and the Director thought there must be a fault, probably running along the valley occupied by the stream above-mentioned, and connected with the faults bounding the Peasemarsh anticline.

The party then walked through the picturesque Albury Warren and by Albury and Shere Heaths, on Folkestone Sands all the way, to Drydown, where Miss Spottiswoode very kindly entertained the members to an excellent tea. After a vote of thanks to the Director, proposed by Mr. E. T. Newton, and a very hearty one to Miss Spottiswoode for her hospitality, the members started across the fields for Gomshall, and returned to London by the 8.5 train, reaching Cannon Street at 9.38.

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Ordnance Survey Map, New Series, Sheet 285.
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1875. TOPLEY, W.—"Geology of the Weald," *Mem. Geol. Survey.*
1894. GREGORY, J. W.—"Excursion to Guildford and Shalford," *Proc Geol. Assoc.*, vol. xiii, p. 337.
1895. GREGORY, J. W.—"Excursion to Chilworth," *Proc. Geol. Assoc.*, vol. xiv, p. 120.
1904. HERRIES, R. S.—"Excursion to Felday, etc.," *Proc. Geol. Assoc.*, vol. xviii, p. 297.
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EXCURSION TO DANBURY AND LITTLE BADDOW.

SATURDAY, JULY 7TH, 1906.

(At the invitation of the Essex Field Club.)

Directors: A. E. BRISCOE, B.SC., MILLER CHRISTY, F.L.S., W. COLE, F.L.S., F.G.S., T. W. READER, F.G.S., AND A. E. SALTER, D.SC., F.G.S.

(*Report by* DR. SALTER.)

THE party, which numbered about twenty-four, assembled at Chelmsford Station soon after 10 a.m., and proceeded in brakes to Great Baddow, where the waterworks were inspected under the direction of J. Dewhirst, Esq., A.M.I.Mech.E., who had placed a sectional diagram of the bore-hole and samples of the various strata passed through for the inspection of the members. His remarks are embodied in the following account:

"The Rural District Council of Chelmsford, Great Baddow, and Springfield Waterworks. Particulars of bore-hole made at Great Baddow.

"The site of this bore-hole is at the outcrop of the clay bed forming the valley of the Chelmer, and is the site also of a strong spring of water draining the gravel which extends from the site to Galleywood, and which for many years was the source of the supply of water for these works.

"The yield of the spring from this gravel formation varies from 60,000 to 120,000 gallons per 24 hours, and is now supplemented by water obtained from the bore-hole.

"The surface level is 97 ft. O.D.; the boring is 311 ft. deep and 10 in. in diameter. It is lined with steel tubes of 10 in. internal diameter to a depth of 350 ft., beyond which are $8\frac{3}{4}$ in. internal diameter perforated steel tubes.

"The work of boring was commenced in February, 1891, and was completed in October of the same year.

"The strata passed through are as follows :

			Depth from Surface.	
	ft.	in.	ft.	in.
Soil	2	0	—	
Yellow Clay	1	6	3	6
Yellow Gravel	10	6	14	0
Red Loamy Sand	1	0	15	0
Yellow Gravel	12	0	27	0
Black Gravel	1	6	28	6
Yellow Loamy Sand	1	0	29	6
Yellow Gravel (very sandy)	9	6	39	0
Brown Clay	1	6	40	6
Blue Clay	68	0	108	6
Clay Stone		6	109	0
Blue Clay	141	6	250	6
Dead Clay Sand	16	6	267	0
Dead Grey Rock	1	6	268	6
Dark Grey Dead Sand	12	0	280	6
Black Pebbles	1	0	281	6
Live Grey Sand	5	0	286	6
Sand and Sea Shells	1	6	288	0
Grey Sand	13	0	301	0
Sandy Clay (mottled)	28	6	329	6
Grey Sand	64	0	393	6
Green Flints	1	6	395	0
Chalk	2	0	397	0

"The rest level of the water on commencing pumping was 80 ft. from the surface, and after continuous pumping day and night for 14 days this was lowered to 145 ft. from the surface, the rate of pumping was 72,000 gallons per 24 hours. In this boring no attempt was made to obtain water by going into the Chalk formation, and other borings in the immediate neighbourhood have proved that little water is obtained from that source.*

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* The following data kindly supplied to Mr. A. C. Young, F.C.S., by Mr. Reginald Watney, may be of interest for comparison :

"WELL SECTION" GREAT BADDOW BREWERY.

			Depth from Surface.	
	ft.	in.	ft.	in.
Dug well	300	0	(No account)	
Broken brick rubbish	16	0	316	0
Hard Clay	10	0	326	0
Claystone	1	6	327	6
Hard Clay	3	6	331	0
Clayey Sand	1	6	332	6
Pebbles	3	6	336	0
Live Sand	11	0	347	0
Hard Clay	5	0	352	0
Pebbly Sand	0	6	352	6
Mottled Clay	6	6	359	0
Sand and Stone	9	0	368	0
Sand and Clay	30	0	398	0
Thanet Sand	48	0	446	0
Chalk and Flints	304	0	750	0

No water in the Chalk. Water came in at 332 ft. 6 in. to 347 ft. and at 359 ft. to 368 ft.

"Pumping from this bore hole is now carried on at from 4,000 to 5,000 gallons per hour by means of an air lift plant, and after heavy continuous work the water level is occasionally lowered to 160 ft. from the surface, but after pumping the water rises rapidly.

"The water is absolutely pure and very soft, as the analysis attached hereto will show.

"James Dewhirst, A.M.I.Mech.E., Engineer."

Copy of analysis by Dr. J. C. Thresh, County Public Health Laboratories, Chelmsford, March, 1902:

"Saline constituents of a sample of water from Great Baddow (Bore) Waterworks:

ESTIMATED IN PARTS PER 100·000.

Ca.	Mg.	Na.	CO.3.	SO.4	Cl.	NO_2	Probable Combinations.	
·8	·325		21·2	7·3	37·6	·2		
·8	...	...	1·2	...	...	...	Calcium Carbonate .	2·0
...	·325	...	·8	...	...	...	Magnesium Carbonate	1·1
...	...	14·7	19·2	...	...	...	Sodium Carbonate .	33·9
...	...	3·5	...	7·3	...	...	Sodium Sulphate .	10·8
...	...	24·45	...	...	37·6	...	Sodium Chloride .	62·05
...	...	...	...	...	...	·2	Nitrates, etc. . .	1·65
	Total solid constituents dried at 180° C. . . .							111·5

"Other determinations:

Hardness, Temporary or Permanent—total	4°
Free Ammonia	0·08°
Organic Ammonia	0·002°
Oxygen absorbed in four hours at 27° C	0·012°
Nitrates	Nil.

"*Note.*—To convert the above parts per 100·000 into grains per gallon multiply by ·7.

"(Signed) JOHN C. THRESH."

The party now proceeded across the road to the large gravel pits known as the Old Bee Hive Quarry, where they were met by the owner, Robert Jackson, Esq., who afforded every facility for the examination of this interesting section.

The gravel is worked to a depth of 45 ft. The lower portion consists of finely stratified gravel, above which is a gravel arranged somewhat tumultuously. In the surface soil above fragments of Roman or Romano-British pottery are occasionally found. Mr. Jackson exhibited to the members some pieces recently obtained

The constituents of the gravel are principally flints, some of which are over a foot long. Sarsens of moderate size occur, the one at the "Beehive" close by having been obtained from this pit. Others were seen lying about. Quartz blocks and large pebbles from the Bunter formation were abundant, and many small boulders of Rhyolite similar to those found at higher levels (*cf.* Beggar Hill, near Fryerning) at 300 ft. O.D. Some large blocks of conglomerate resembling Hertfordshire pudding stone also occur.

The materials appear to be derived from higher and older gravels which formerly existed to the south and west.

After heartily thanking Mr. Jackson the party returned to the brakes and proceeded to Danbury Court, where, under the guidance of Sir Thomas Hanbury, K.C.V.O., a pleasant hour was spent viewing the house and its lovely grounds.

After lunch at "The Griffin" a visit was paid to the church at Danbury, and a full and interesting account of it was given by the Vicar. Danbury Common, 300 ft. O.D., was then crossed in order to view the large excavations for gravel which are to be seen there. Dr. Salter pointed out that Danbury Hill owed its existence to the sheet of gravel which capped it, and which had resisted denudation while the softer clay land around had disappeared. The gravel, sand, and clay were much contorted, and the Director pointed out that these might be due to one or more of the following causes:

(*a*) The former presence of calcareous beds below the gravels, which, on being dissolved away by the water percolating through the gravel and sand, caused the superincumbent insoluble beds to fall in. This explanation is not probable, as the only calcareous beds likely to occur would be Crag, and of these there are no signs.

(*b*) Earth-movements of a wide-spread character.

(*c*) The slipping of the subjacent London Clay down the steep slope, thus disturbing the gravels, etc., above. In this connection it is noteworthy that an important spring occurs close by at a rather lower level.

(*d*) The impact of an ice-sheet. Mr. F. W. Harmer, F.G.S., writing to the Director regretting his inability to attend the excursion, wished him to state that he believes "the mounds of gravel, etc., at Danbury and Tiptree Heath represent the terminal moraine of the Essex ice sheet, rather than the denuded remnants of a once more widely-spread deposit."

The Director pointed out that the constituents of the gravel showed it belonged to the same series of deposits as are found at Beggar Hill, around the Stevenage Gap, and along the northern slope of the Lower Thames Valley at various localities, which he regarded as of fluviate origin. The time allowed did not permit of a thorough examination of all the interesting points connected with this important deposit, and it is to be hoped that in the near future another opportunity for doing so will arise.

From Danbury the party walked across Lingfield Common to Little Baddow, and visited the church and the old Independent chapel there. In the latter John Eliot, the "Apostle to the Indians," preached before embarking on the *Lyon* for Boston.

The party were then hospitably entertained by Mr. and Mrs. Briscoe at the Hoppet, and, after tendering their thanks to them and the Directors, resumed the conveyances for Chelmsford and returned to London.

REFERENCES.

Geological Survey Map, No. 1, N.E.

Ordnance Survey Map, No. 241.

1889. WHITAKER, W. "Geology of London," vol. i.

1904. SALTER, A. E. "On the Superficial Deposits of Central and Parts of Southern England," *Proc. Geol. Assoc.*, vol. xix, pp. 30, 31, where other references are given.

EXCURSION TO BENTLEY, SUFFOLK (CRAG).

SATURDAY, JULY 14TH, 1906.

Director: E. P. RIDLEY, F.G.S.

Excursion Secretary: A. C. YOUNG.

(*Report by* THE DIRECTOR *and* MR. BOSWELL.)

A PARTY of fifteen left Liverpool Street Station at 11.45, and arrived at Bentley Station at 1.30, where they met an equal number of members of the Ipswich Scientific Society.

The first visit was to a new pit which was opened in the Red Crag close to Bentley Station in the winter of 1905. It lies about 300 yards east of the station. Mr. Boswell had been at work here all the winter, and by the kind permission of the owner, the Hon. Stanhope Tollemache, and the occupier, Mr. Southgate, has been able, with the help of a labourer, to sift the crag according to Mr. F. W. Harmer's method (*Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 717).

The fauna of the crag deposits between the Rivers Orwell and Stour had not been properly worked out, and there was some doubt as to whether these deposits should be referred to the Newbournian Zone, or the Waltonian, of Mr. Harmer's classification.

At present the work is proceeding, and is thus incomplete, but he had succeeded in sifting about 5 tons or more of Crag, obtaining rather over 100 different species of mollusca, polyzoa, etc. These serve to show that in this particular section the fauna is decidedly more Waltonian than Newbournian in its affinities. Mr. Harmer informed him that S. V. Wood always held that opinion.

For this visit he had been working overnight and since six o'clock in the morning sifting for fossils, so that all the members were able to get a large number of very good specimens. His friend, Mr. S. J. Batchelder, had kindly taken a large number of photographs of the actual working, and of the crag sections, illustrating decalcification, induration, and current-bedding, prints of which he distributed among the members of the Association.

The party then proceeded to the Park Farm, Tattingstone, to examine the section figured and described by Sir Joseph Prestwich, but the coralline crag has now entirely disappeared, and no traces of it could be found. After visiting another red crag pit nearer Tattingstone White Horse, the party were very hospitably entertained to tea by Mr. and Mrs. Booth at Bentley Lodge, and the members returned to London from Bentley at 8.5 by a train, specially stopped for the party, having had a very pleasant day's excursion and a very good opportunity of collecting in the Red Crag.

REFERENCES.

Geological Survey Map, Sheets 48, N.W. and N.E.
Geological Survey Index Map, Sheet 12. Price 2s. 6d.
1885. PRESTWICH, SIR JOSEPH—"Crag Beds of Suffolk and Norfolk," Part II, *Quart. Journ. Geol. Soc.*, vol. xxvii, p. 325.

EXCURSION TO BOROUGH GREEN, ETC., AND IGHTHAM.

SATURDAY, JULY 21ST, 1906.

Directors: F. J. BENNETT, F.G.S., AND B. HARRISON.

Excursion Secretary: G. E. DIBLEY.

(*Report by* THE DIRECTORS.)

ARRIVING at Wrotham Station at 2.40, a party of twenty-two, Mr. F. J. Bennett took the first and Mr. B. Harrison the latter part of the direction. The first section seen was that in the sand pit just north of Borough Green Station, and consisted of a Drift deposit of Loam and Gravel, resting on the north flank of a slope of

Folkestone Beds close by, but the junction with the Gault is not visible, though the Gault is exposed in the brickyard.

The first point to be noted was the immense amount of denudation that had taken place to form the Chalk escarpment, part of which they saw before them, and the paucity of the resultant Drifts.

The factors that caused that denudation, and Mr. Bennett believed that it could be referred to no one cause, and the paucity of these Drifts were, he submitted, problems still to be solved.

So impressed had he been with the fact that some of the Drift due to the waste of the Chalk scarp must still be left, that since his settlement in this district, now some seven years, he had spent much time in searching for this drift. He thought he had found it, and they would see a section in this shortly.

He then pointed out the reasons that led him to look out for a Chalky rather than for a Flinty Drift, which he had termed Scarp Drift, and in the excursion to Cuxton, June 4th, 1904, some important sections in this were visited under his direction.

The section before them showed the combination of two Drifts, and Mr. Harrison, he believed, agreed with him in this, viz., the well-known Southern Drift (with a difference, perhaps) of Prestwich, here also known as Plateau Drift, and the new Drifts he had termed Scarp Drift. In the above excursion of June 4th, this was seen to rest on the Southern Drift (redeposited) in the Aylesford Gravel Pit, and to be mainly composed of chalky material—indeed the men there call it "mortar."

Though this Plateau Drift was a very widely distributed one, it consisted—especially in the area in question—of small, isolated patches, and they had to thank Mr. Harrison for his life-long work in this area, for the discovery of these patches, and for much of what they would see to-day. He (Mr. Bennett) had found a similar Drift at Seaford, at the cliff near the old camp; and from there he and his friend, the Rev. J. D. Gray, of Nayland, had got nothing but Eoliths, as was the case here, and they had also seen a similar Drift capping the Chalk cliff near the golf links at Newhaven, but had only paid one visit to that. These isolated patches must be the remnants of a once very large mass, which had vanished with the departed crest of the Weald.

This section again was a most important one, as it was the only Plateau Drift section yet found off the Chalk Plateau, and in which Eoliths only, after much diligent search, had been found.

Now, if this represented the true Plateau Drift it could have no relation to any existing rivers; how, then, could they account for its existence in the position they found it? That, he submitted, was a difficult problem to solve, and the only solution that occurred to him was that, as this must once have capped the chalk that must once have been above them, it was the insoluble residue of what had intervened, and that it had been let down by solution into its present position. This, of course, was very difficult of acceptance, but he had seen much lately in the district that made this more easy of acceptance by him than, no doubt, by them.

He next called their attention to the loam, thin and sandy at the upper part, but thicker and stiffer at the northern and lower part, due, he considered, to its nearness to the outcrop of the Gault. This loam he referred to the decalcification of the chalky Scarp Drift.

They next visited the Gault exposure close by, dug for making bricks, and here capped by a brown loam which was seen to pass into a pellety Chalk Drift, and due, he considered, to the decalcification of that Chalky Drift.

This chalky Scarp Drift he classed as a Residual Drift, a term, he considered, much needed to distinguish it from Drifts of Transport brought from a distance, and containing matter foreign to the district.

He next commented on the absence of any fossil remains, and contrasted that with what had been found in the famous Ightham Fissure discovered by Mr. Harrison in 1891, when he found there the bones of an extinct badger. This fissure has been most assiduously worked by Mr. W. J. Lewis Abbott, F.G.S., and others.

The party next proceeded along the high road towards Wrotham, passing over what Mr. Bennett termed an old flood plain of the Shode, as shown by a spread of flint drift, much denuded and cut through in places. Turning off to the west they proceeded towards Newhouse Farm. About half-way a stop was made at a road-cutting. Here Mr. Bennett pointed out a section in Scarp Drift, showing some 7 ft. of Chalky Drift over Lower Chalk with some shells at the base. These appeared to belong to living species of land shells, and they may have made their way down by worm action, etc., as suggested by Mr. Elgar, one of the curators of Maidstone Museum, had found instances of living land shells let into the Gault through cracks in the soil, etc.

Mr. Bennett then called attention to the flat terrace-like feature through which this cutting was made. He pointed out how these terraces ran right up to the foot of the Chalk Scarp concealing the true valley bottoms, and being, he considered, distinctly drift features.

He showed also his new Drift Survey Maps, showing the extent in the area in question he had mapped of this Scarp Drift, the base-line of which coincides roughly with that of the railway.

Of this base line he thought he might say that it approximately marked the position of the Chalk Scarp at a later stage of its existence.

A little farther on, the site of the Bourne-source of the Shode was pointed out north of the road close to Newhouse Farm, where it rises at long intervals, the last time in 1902, when it flowed for about 14 days.

Mr. Harrison then took the leadership, having previously pointed out the site of Blacksole field.

On reaching the summit of the chalk escarpment he pointed out the site where the excavations were made for a reservoir.

The sections which were shown during the course of that work yielded Gault fossils which could only have been derived from a now vanished southern upland. Many of the specimens were found *in sitû* in the drift at this place by Mr. Harrison. Among them the following species were identified by Mr. Crick, of the British Museum, *Hoplites interruptus*, Brug., *Hystotoceras variosum*, Sow., *Hamites* sp., *Belemnites minimus*, List., *Antinoceramus sulcatus*, Park.

The site of a pit dug close to the road and S.E. of the reservoir was also seen, and from this many Eoliths had been obtained.

Mr. Bennett had noted the following section here in 1902 at about 760 ft. O.D. Top soil of the meadow, then a very compact gravel with many ochreous flints and Eoliths, some being very small. Some pieces of Greensand chert were also found. This gravel at first escaped notice until the pick was used. It was tightly packed in a stiff clayey matrix. Its thickness varied from 1 ft. 9 in. to 2½ ft., and it seemed to become thicker to the west. This gravel rested on red and yellow mottled clay, with some very large unworn flints. Four feet of this clay was sunk into one place with no particle of change.

When the reservoir was made, a cutting connecting this with the road and close to the site and 6 ft. deep showed mostly red mottled clay, with very few flints, but in one place they were closely packed together. Clean, fine, brown sand was touched in one place beneath the red clay, which might be classed as Tertiary Sand. It also contained pebbles, and some of these so weathered as to look like chalk, and these crumbled easily under pressure. These pebbles are to be seen in the Knokwell Pit, two miles to the N.W.

A move was made to the pit sunk by Mr. Harrison at the summit level 770 O.D. Here is a similar section to that described, only that the gravel bed is not so well defined, and that at one place in the red mottled clay was a pipe of what looked like typical clay with flints.

Mr. Bennett then suggested that it might be classed as a glacial deposit, a kind of Boulder Clay made from Tertiary Clays, and clay with flints caused by ice coming off the vanished crest of the Weald, for if that were 2,000 ft. higher than now, surely that elevation might have given rise to glacial conditions of a kind.

The party then proceeded by the old Hollow road, a very ancient trackway down the face of the chalk escarpment to the road leading to Ightham.

On the way down, at the 700 ft. level, Mr. Harrison called attention to a curious bed of Chalk, Pebbles, and Flints, cemented into a hard breccia, which was lying on the flank of the slope. This bed was so hard that, when broken with the hammer, the fracture passes through flint and chalk pebbles alike. A similar breccia is found at Shoreham and at Trottersclift, and Sir J. Prestwich regarded it as marking an old saturation level.

On reaching Ightham the party partook of a hurried tea at the George and Dragon, and the greater number returned to London by an early train. The Excursion Secretary and one or two other ardent spirits resolved to brave the terrors of the last train. They were rewarded by a very fine exhibition of Eolithic implements, which Mr. Harrison had prepared in the village hall. Afterwards they had a charming walk towards Yaldham Manor to see some enormous blocks of Oldbury Stone which now rest on the Gault, and which must have been transported by ice acting in some form or other down and up the branches of the Shode valley from Oldbury Hill.

A vote of thanks to the Directors terminated the proceedings.

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LONG EXCURSION TO THE YORKSHIRE COAST.

JULY 23RD TO 31ST.

Director: THE PRESIDENT (R. S. HERRIES, M.A., V.P.G.S.).

Excursion Secretary: H. KIDNER.

(*Report by* THE DIRECTOR.)

THE party travelled down to Whitby on Saturday, July 21st, by the 11.30 a.m. train from King's Cross, arriving at 5.30 p.m. The headquarters were at the Crown Hotel, but several of the members stayed at the West Cliff Private Hotel. The whole party numbered thirty-eight. The object of the excursion was to see the cliffs from Robin Hood's Bay to Redcar, so as to embrace all the coast sections of the Yorkshire Lias, the Liassic sections of the Dorset coast having been explored at Easter. The first three days were to the south of Whitby, the next three to the north. This coast north of Whitby had not before been visited by the Association.

MONDAY, JULY 23RD.—Leaving the Crown Hotel about 9 o'clock, the party crossed the River Esk by the bridge, and walked through the old town to the East Pier. Here the Director gave a short account of the geology of the district and particularly of the immediate neighbourhood of Whitby. The cliffs in front, on which stand the Abbey and Church, are composed of a base of Upper Lias (zone of *Ammonites communis*) with Oolite (Dogger and Lower Estuarine Beds) above, while the West Cliff, on which the new town is built, consists of sandstones and shales of Lower Estuarine age, the Lias and Dogger having been thrown down by a fault which runs along the course of the river. Farther west the Oolite Beds are cut out almost entirely by a thick deposit of Boulder Clay and Sands of glacial origin, which fill the bay as far as the village of Sandsend, where the Upper Lias Beds are again seen forming Sandsend Ness. Looking in the other direction, the curiously shaped, long, low promontory of Saltwick Nab was pointed out, and the party then descended to the scar and walked in the direction of Saltwick. The Director explained that the term "scar" was applied to the flat platforms of rock which generally form the foreshore under the cliffs in this district. In this many of the characteristic ammonites and belemnites of the Alum Shale were seen, though the former are often quite flat, as they generally are when not found in nodules. About half-way to Saltwick the Dogger comes down to the shore level, and is seen to be a hard ferruginous band about three feet thick, with a layer of pebbles at the base. These pebbles are mostly small phosphatic nodules, but worn fragments of ammonites and other shells derived from the Lias are not uncommon. At this point the Dogger seems to fill a hollow in the surface of the Lias, pointing to an unconformable junction.* The Lower Estuarine Beds above are here very full of plant remains, and several good pieces of fern were obtained. The Dogger then rises in the cliff and four hard reddish bands in the Lias cross the scar in succession and appear in the cliff, the lowest being rather below the neck of Saltwick Nab. At the base of the Nab a change of fauna was seen, *Ammonites communis* and its allies being replaced by *serpentinus*, and the horizon is marked by an abundance of *Inoceramus dubius*. This change indicates that we are on a new zone, that of *Am. serpentinus*, marking the horizon of the Jet Rock as that of *Am. communis*

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* See Fig. 1 in Mr. R. H. Rastall's paper, *Quart. Journ. Geol. Soc.*, vol. lxi, p. 450.

does the Alum Shale. The party walked round the end of Saltwick Nab and out seawards to the reef of strong hard nodules, known as the "cheese" doggers from their resemblance to huge cheeses. They are often five or six feet in diameter, and are noted as forming the roof of the jet-bearing strata. Hammers and chisels were soon at work splitting off flakes of the hardened shale encasing these doggers in the hope of securing the small fish, *Leptolepis saltviciensis*, but the search was unsuccessful. Plenty of specimens of *Posidonomya Bronni* were however obtained, this shell being very characteristic of the lower part of the zone of *Am. serpentinus*, and, coming round the south side of Saltwick Nab, several examples of the long flat *Belemnites tubularis* were found. After luncheon at the foot of the great amphitheatre caused by the excavation of the Saltwick cliffs for alum, the party proceded to Black Nab, the fortress-like rock on the south side of Saltwick Bay, which forms an island at high tide, the base of which consists of *Serpentinus* shales. Before reaching it the Director pointed out a place where one of the red bands, now again at the shore level, was composed of a mass of belemnites, hundreds of specimens being crowded together in the space of a few feet.

The rising tide prevented any further progress along the shore, so the members ascended the cliff by a rather steep path, some preferring to retrace their steps to the easier way up in the middle of the bay. They walked along the top of the cliff, past the siren and lighthouse to High Whitby, whence the cliffs could be seen stretching away towards Robin Hood's Bay. High Whitby is a very bold cliff where the coast turns southwards. It is mostly composed of Lower Estuarine Beds which come down nearly to the shore level, and it is here that the well-known *Equisetum columnare* is found in the sandstone, upright as it originally grew. The path down is, however, a very steep one, and no one ventured to descend, especially as the Director would not undertake to guarantee the bed of *Equisetum* being found. The party returned along the cliffs to the Abbey, where they were met by the rector, Canon Austen, who had most kindly volunteered to show the members over the ruins. Some delay was caused by a heavy thunderstorm which broke over Whitby just as the party had arrived at the Abbey gates, but when it had stopped the members had the advantage of listening to a most interesting discourse on the history and architecture of the Abbey, after which Canon Austen led the way to the old Church, certainly one of the most curious in the way of internal fittings to be seen anywhere in England. After the lecture the President proposed a vote of thanks to the rector, which was heartily responded to, and the members then proceeded to descend the long flight of steps to the old town, and crossing the bridge found their way to the museum, where Mr. Thomas Newbitt, F.G.S., the honorary curator, was waiting to show them over. The museum is of great interest, having a very fine collection of Lias fossils, amongst which are some very good saurians and most of Simpson's numerous types. In thanking Mr. Newbitt, the President congratulated him on the excellent order in which the collections under his charge were kept.

TUESDAY, JULY 24TH.—The party left the West Cliff Station by train at 9 o'clock for Robin Hood's Bay, arriving at 9.20. At the top of the steep road leading down to the quaint little town, the Director pointed out the features of the bay. To the south was the great cliff of Peak, some 600 feet high, where the well-known fault brought the *Capricornus*-zone of the Lower Lias against the Lower Estuarine Beds of the Oolite. The cliffs north of the fault were composed of Lower Lias of the *Jamesoni* and *Oxynotus* zones, except where they were interrupted in two places by masses of Boulder Clay. Along the foreshore the scars were seen spreading out in a graceful horseshoe-like curve, those nearest the cliff belonging to the *Oxynotus* and those farther out to the *Bucklandi* zones, while immediately in front of the town they were the *Armatus* beds of the *Jamesoni*-zone. The beds here, as the Director explained, form a dome or anticline, the lowest beds seen anywhere along the Yorkshire coast (except at Redcar) being here exposed. Between the Peak and the hill on which the party were standing, the rich valley known as Fylingdales was spread out, the bottom of which was mostly composed of Boulder Clay flanked by Upper Lias, which was well marked by the great alum pits of Peak and Stoupe Brow.

A descent was then made to the shore, and the Director took the party across the *Oxynotus* scars on to the *Bucklandi* beds opposite Mill Beck. There was not time to do much collecting, but some of the characteristic fossils of the *Oxynotus*-zone were found, including *Am. raricostatus*, *Am. obtusus*, and *Bel. acutus*. Some large boulders of Shap granite and other igneous rocks were noticed on the shore, and the Rev. C. T. Pratt, who formed one of the party, gave some account of the sources of origin of these large boulders. The party then turned northwards, passing Bay Town, and proceeding along the *Armatus* and *Jamesoni* scars towards the North Cheek. Most of the characteristic fossils of these beds were seen and collected, such as *Am. trivialis*, *Gryphæa cymbium* (var. *obliquata*), *Pecten æquivalvis*, *Plicatula spinosa*, *Pholadomya decorata*, and *Pinna folium*. Passing on to the overlying *Capricornus* shales the sandy beds of the same zone were next seen at Castle Chamber, just beyond the North Cheek. The Director explained that the Geological Survey place their division between the Middle and Lower Lias at this horizon on lithological grounds, thus dividing the zone, whereas Tate and Blake include not only the shales of the *Capricornus*-zone but the whole of the *Jamesoni* beds in the Middle Lias. This was on palæontological grounds, and seemed to the Director to be the more correct view, but not of course so convenient for mapping. For the purposes of this report, however, he would speak of the *Capricornus* and *Jamesoni* beds as Lower Lias. These sandy beds of the *Capricornus*-zone are marked by a series of oyster beds formed of masses of *Gryphæa cymbium* (var. *depressa*). There are also near the top one or two beds of the large *Dentalium giganteum*, which here occurs in great profusion and again in a few layers in the zone above (*Margaritatus*), after which it dies out altogether.

The beds at Castle Chamber form a sort of miniature escarpment on the scar, some ten or twelve feet high, and the same thing occurs at Dobson's Nab, the next point, where the sandy series of the *Margaritatus*-zone runs out. Both these points presented some little difficulty to the party and required some negotiating. It is not at all a nice place with an on-shore wind and a rough sea. Luckily, however, the sea was quite calm and an ample margin had been allowed for the tide, so that these difficulties were reduced to a minimum. A halt was now made for luncheon, after which the walk was continued round the little bay south of Normanby Stye Batts where the ironstone beds of the *Spinatus*-zone are so much in evidence. This bay is very picturesque, the cliffs being very lofty and steep, capped by the Alum Shale with the Jet Rock below, the old workings of the latter being seen near the top of the cliff. Several of the ironstone doggers were broken up and a fair number of fossils obtained, including *Am. spinatus*, *Pecten æquivalvis*, *Pleuromya costata*, etc. The next beds seen were the *Annulatus* beds or Grey Shales, in which the zonal ammonite and *Bel. cylindricus* were found. Passing over these the next beds are those of the *Serpentinus*-zone or Jet Rock, now come down to the shore, and here the scars begin to be obscured by large blocks fallen from the Oolitic rocks which form the upper part of the cliff, a condition of things which extends as far as High Whitby, so that the path up the cliff known as "Sawdons Road," which leads to Hawsker Bottoms, comes very opportunely at this point. Up this rather narrow path the party went, seeing on the way a good section of the Lower Estuarine Beds with a coal bed of quite respectable thickness. From Hawsker Bottoms the return to Whitby was made on foot by the cliffs, the members one and all scorning the alternative route by train from Hawsker station. A welcome halt was made for tea at the old alum pit at Saltwick, and another at a fossil stall near the Church, where a considerable number of fossils changed hands at very reasonable prices. The Association were fortunate in having with them on this and on several of the subsequent days, Dr. Gothan, of Berlin, who had come to Whitby specially to study the jet working, and gladly accepted the President's invitation to join in the expeditions.

WEDNESDAY, JULY 25TH.—The members again left the West Cliff station by the 9 o'clock train, alighting at Ravenscar at 9.39. Ravenscar is the name which has been given within the last few years to the district formerly known as Peak, on the south side of Robin Hood's Bay. The estate has been developed for building, and a series of roads made, but the houses have not sprung up very rapidly, probably owing to the bleak character of the place, which is about 600 ft. above the sea, though it is pleasant enough in the summer. The Director first led the party a little way back to a point where there was a view over the bay, and directed special attention to the great Peak alum quarry, through which the train had come when climbing the hill to Ravenscar station. A conspicuous band about 3 ft. thick is seen resting immediately on the Blue Lias clays (*Communis*-zone). This was explained to be the Dogger, and it was approximately at the same level as the point where they were standing, viz. about 600 ft. above the sea. The quarry was on the west side of the great fault which runs in a north and south direction, and comes out on the shore at the Peak. The Director asked the members to bear this in mind when they saw the Dogger on the other side of the fault, about 30 ft. thick, with some 150 ft. of beds below it, which are quite unrepresented in the Peak alum quarry. Returning towards the station the members were rewarded by a magnificent view over the whole coast to the south as far as Flamborough Head, it being a particularly clear day. Scarborough Castle, Filey Point, and Flamborough Head were very clear, and the sun was shining on the white chalk cliffs of Speeton. A little south of the station a somewhat rough path was taken down the cliff to the place a few hundred yards south of Blea Wyke point where the Dogger rises from the sea. A few of the party preferred the excellent path which leads down to Blea Wyke itself, but this involved a double journey over the rough boulders between the point and the spot where the party were assembled. The cliffs between here and Hayburn Wyke, known as the Staintondale Cliffs, are very high and picturesque, not perpendicular, but with sometimes one and sometimes two terraces or undercliffs prettily covered with bracken, heather, and shrubs of various kinds. The top of the cliff is sandstone of Upper Estuarine age, below which is a considerable thickness of Grey or Scarborough Limestone, from which several fossils were collected at an exposure by the side of the path. Then follow in succession the Middle Estuarine, the Millepore Oolite, and the Lower Estuarine and Ellerbeck Bed, with the Dogger at the bottom. About 10 ft. from the top of the Dogger the very fossiliferous bed known as the "Nerinæa bed" was found, and many beautiful fossils (*Nerinæa*, *Cerithium*, *Natica*, *Alaria*, *Trigonia*, *Astarte*, etc.) were obtained, both from the bed in place, and from fallen blocks passed on the way to Blea Wyke. The members scrambled along over the boulders, the successive nodule or pebble beds being pointed out, as well as the "Terebratula bed" at the top of the Yellow Sands, the uppermost division of the Blea Wyke or Passage Beds, which only occur at this place. Besides the *Terebratula trilineata*, which occurs in great profusion, the Yellow Sands contain numerous belemnites and large, somewhat flattened ammonites, with smooth outer whorls and strongly ribbed centres. At the foot of the Yellow Sands the party came out on the flat platform of rock forming the base of Blea Wyke point (Plate VIII, Fig. 1). This is the "Serpula Bed," being the upper part of the Grey Sands, or lower division of the Blea Wyke Beds. Many specimens of the *Serpula*, which gives its name to the beds, were found, as well as more ammonites similar to those in the Yellow Sands. Coming round the point into the little bay known as Blea Wyke, the lower division of the Grey Sands forms a second and lower platform, and is known as the "Lingula Bed," from its containing nodules full of *Lingula Beanii* accompanied by *Discina reflexa*, both of which were obtained.

After luncheon the walk was continued as rapidly as the rock-strewn shore would allow, the exposures of the *Jurensis*-zone of the Lias being noted. These beds are immediately under the Blea Wyke Beds, and like them are only seen in this section. They are generally called the "Striatulus Beds," from the ammonite which is most commonly found in them. There being a strong dip to the south, the beds soon rise up into the cliff (Plate VIII, Fig. 2) and are succeeded in turn by the zones of *Am. communis* and *serpentinus*, the shales of the latter zone occupying the base of the cliff at the fault. Here the Director put one hand on the beds of the *Serpentinus*-zone and the other on those of the *Jamesoni*, and taking the party a little way up the path which comes down almost on the line of the fault, he pointed out that higher up the Lower Estuarine Beds and Dogger were faulted against the *Capricornus* beds of the Lower Lias (Plate IX, Fig. 1). The change of dip of the former to the west towards the fault was noticed. The line of the fault was also well seen on the reef running out to sea, known as Peak Steel, the Lower Lias *Oxynotus* beds being faulted against those of the zone of *Am. margaritatus*, belonging to the Middle Lias. The fault here divides into two branches, so that the *Margaritatus* beds form a kind of wedge, being themselves faulted on the other side against beds of the zones of *Am. annulatus* and *spinatus*, with a strike nearly at right angles. The Director enlarged on the questions arising from the fact of the existence of the considerable series of Blea Wyke and Striatulus Beds on one side of the fault which were absent on the other, though the fault is itself of a much later age, affecting all the overlying oolitic beds. Various theories may be found set out in the paper read by the Director in advance of the excursion (*supra* p. 419). The walk was continued round Robin Hood's

FIG. 1.—BLEA WYKE.
(Compare diagram, *supra*, p 421.)
Photo by Godfrey Bingley.

FIG. 2.—PEAK (LOOKING TOWARDS BLEA WYKE).
(Showing *Jurensis* beds under Blea Wyke beds and Dogger.)
Photo by Godfrey Bingley.

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Bay to Bay Town, but there was very little time left for examining the *Jamesoni* blocks near Peak, or the *Oxynotus* scars, while those of the *Bucklandi*-zone were already covered by the rising tide. Tea was obtained at the Victoria Hotel at Robin Hood's Bay, and the party returned to Whitby by the 4.57 train, arriving at 5.16.

THURSDAY, JULY 26TH.—The members left the West Cliff station by the 9.43 train for Sandsend, arriving at 9.50. The railway follows the coast, and between Whitby and Sandsend passes over Boulder Clay. At Sandsend the Lias again appears and juts out in the cliff known as Sandsend Ness, which can only be rounded on the shore when the tide is very low. Permission had therefore been obtained from the North Eastern Railway Company to walk along the line through the old alum quarries as far as the next little bay, known as Deepgrove Wyke. The alum quarries showed a good section of the *Communis*-zone of the Upper Lias with the Dogger, here about three or four feet thick, above, capped with Lower Estuarine Beds. The Dogger is fossiliferous, but not so much as it is a little farther north. The .working of alum from the Lias shales has long since been abandoned as a profitable undertaking, but cement is still manufactured under the name of Mulgrave Cement from lines of large septaria-like nodules in the upper part of the Alum Shale. At Deepgrove the party descended to the shore by a somewhat precipitous apology for a path, and found themselves on a scar of the *Serpentinus*-zone. From here to Kettleness there is almost a continuous line of artificial caves at the base of the cliff, or a little way above, marking the course of the "Jet Rock" (Plates IX, Fig. 2, and X, Fig. 1). These caves are the old workings made by the seekers after the jet in the days when "Whitby Jet" was a well-known and profitable article of commerce. The trade is not as prosperous as it once was, and though there is still probably as much jet in these cliffs as ever came out of them, it is hardly worth while nowadays for anyone to pursue the somewhat laborious and uncertain occupation of jet mining. Except that it is found, as already explained, within certain well defined limits, its mode of occurrence is quite casual and follows no rule. A man may hew a great quantity of shale without result, or he may at any time be rewarded by a find of jet, large or small. A discussion took place on the origin of jet, which has been variously ascribed to fossilised wood, or to hardened bitumen filling up hollows, often those left by decayed wood, in which cases it would simulate the outward form of the wood. Messrs. Tate and Blake supported the latter theory, and it is certain that there is a considerable amount of bituminous matter in the rocks, which when fractured often smell strongly of that mineral. Moreover, the chambers of ammonites and the phragmocones of belemnites are often full of it in a liquid form, and it is only where the bitumen is present, that the jet is found. Dr. Gothan, however, who was present and had made a special study of the subject, had no hesitation in adopting the older theory that jet was actually fossil wood. He explained that he had found that certain recent woods which had remained a long time under water in some brickfields, on being taken up and allowed to dry with the clay, would shrink, and become very hard and compact like jet.* This was what had happened in the case of the fragments of wood which were now found at this horizon of the Lias in the form of jet. He was in agreement with Dr. Seward, of Cambridge, in attributing a vegetable origin to the jet. From Deepgrove Wyke the walk was continued along the shore to Overdale Wyke, where the Grey Shales or *Annulatus* beds come up and form the scar. Here specimens were obtained of the zonal ammonite. Rounding the point the *Serpentinus*-zone is again at the sea level, and so continues round the wide bay nearly as far as Kettleness, where the Grey Shales again occupy the foreshore. Along the whole way from Deepgrove to Kettleness ample opportunities are afforded of obtaining the characteristic fossils of the Jet Rock, both from the scar and from fallen blocks and nodules, and several good specimens were obtained of *Am. serpentinus*, *Am. exaratus*, *Am. gracilis*, etc. Some of the fallen blocks are from the *Communis*-zone, and these, too, yield many fossils. At one point of the bay there has been a considerable slip from above, and a large amount of Dogger material has come down. This is very fossiliferous, though the fossils are in the form of casts. Anyone, however, who chose to take moulds from the external casts which may be collected here, might form a fairly complete collection of Dogger fossils. *Terebratula trilineata* is specially abundant, and the fact that it is associated here with the fossils which at Blea Wyke occur some 20 ft. higher up, shows that not much reliance can be placed on its presence as marking a special horizon. At Kettleness Point (Plate X, Figs. 1 and 2) the Grey Shales ascend into the cliff, and the Ironstone series or zone of *Am. spinatus* occupies the scar. A succession of ironstone bands alternating with shales is here seen as at Hawsker, but the ironstone is thicker. Fossils are abundant, especially *Am. spinatus* and *Pecten æquivalvis*. There are several algæ-like branching forms on the surface of some of the ironstone beds, to two of which Prof. Tate gave a name; the larger of these is *Chordophyllites cicatricosus*, and the smaller *Nulliporites furcillatus*. Dr. Gothan, when asked, did not care to commit himself as to whether they were of organic origin or not. Rounding Kettleness Point the beautiful Bay of Runswick (Plate X, Fig. 2) comes into view, with the village on the north side and the promontory of Old Nab forming the opposite point, somewhat comparable to, though smaller than, Robin Hood's Bay.

The party walked round the bay, passing again over the Grey Shales and Jet Rock, then the *Spinatus* beds, and then the Grey

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* "Ueber die Entstehung von Gagat und damit Zusammenhängendes," by Dr. W. Gothan. *Naturwissenschaftliche Wochenschrift*, Jan. 7th, 1906.

FIG. 1.—KETTLENESS FROM THE SOUTH.
(Showing old Jet workings.)
Photo by Godfrey Bingley.

FIG. 2.—RUNSWICK BAY AND KETTLENESS FROM THE NORTH.
(Showing old Alum workings with Ironstone at Base of cliff.)
Photo by Godfrey Bingley.

Shales once more, these beds alternating on the scars in a curious manner without any apparent faulting. The middle of the bay is composed of glacial drift, and some blocks of Shap granite were noticed on the beach at Runswick. The party climbed to the top of the cliff by the somewhat primitive ways which lead through the village and had tea at the Runswick Bay Hotel. Thence they walked to Hinderwell station and returned to Whitby by the 6.28 train, arriving at 6.49.

FRIDAY, JULY 27TH.—Starting from the West Cliff station at 9.43, the party should have arrived at Skinningrove at 10.29. They were about an hour late, however, owing to the engine being unable to draw the train up the steep incline between Sandsend and Kettleness. As the train came to a standstill in the middle of a long tunnel, for which no lights are supplied, and then began to back down the incline, the experience was a somewhat alarming one. A carriage had to be left at Sandsend, and with the load thus lightened the engine at its second attempt proved equal to the task. Skinningrove is situated in the Cleveland mining district, and the walk of nearly a mile from the station to the shore lay between mines on the one side and blast furnaces on the other, and a constant succession of trucks were seen passing, carrying the ore from the mines to the furnaces. The village lies in a pretty bay facing nearly north, with the huge cliff of Boulby or Rockcliff on the east, and the more graceful, though less lofty, Huntcliff on the west. The cliffs in the middle of the bay are composed of the usual glacial drift, though this is in places replaced by still more recent slag tipped over from the furnaces on the top. The walk was eastwards past Hummersea cliffs, under the old Loftus alum works, round Boulby cliff, to Staithes. The Hummersea cliff is composed of the *Capricornus* beds below, with the *Margaritatus* and *Spinatus* beds above. After this the cliff rises rapidly to a height of over 600 ft., forming Boulby cliff, the highest point being 666 ft. which is almost, if not quite, the highest cliff in England, though one of the members stated that he believed that height was exceeded by a cliff in Cornwall. The upper part of the cliff was the Oolite (Lower Estuarine Series), and the base was the *Jamesoni* beds of the Lower Lias. At the Loftus alum works the Dogger and passage beds were well developed, though not to such an extent as at Blea Wyke. The Alum Shale and the zones below, both of the Upper and Middle Lias, as well as the *Capricornus*-zone, were all present in full force. The *Jamesoni* beds are particularly fossiliferous, and their appearance is marked on the scar by a line of nodules containing *Am. fimbriatus*, which may be taken as the base of the *Capricornus*-zone. After that they rise in the cliff to a height of about 25 ft., and yield *Am. Jamesoni*, *Am. trivialis*, *Pinna folium*, *Pholadomya decorata*, etc. Part of a large saurian was seen in the scar. There is a remarkable slip of old date on the west side of Boulby cliff, nearly the whole face of the cliff having slid down for a distance of about 100 yards, so that the beds are seen on the scar in a vertical position with a strike parallel to the line of the cliff. The ironstone series is particularly well shown, and the thickness of the various seams is easily measured. About two miles before reaching Staithes the cliffs again resume their normal height, and the *Jamesoni* beds come down again to the sea level and pass out to sea. At Colburn Nab, just west of Staithes, there is a very good section of the sandy series of the *Capricornus*-zone, which has yielded many starfish to collectors. Several specimens, more or less fragmentary, of *Ophioderma* were found in the fallen blocks near here, and Mr. A. C. Young was fortunate enough to find one of the Asteroid variety, which are much rarer. The picturesque and other qualities of the curious little fishing town of Staithes were duly appreciated, and after partaking of tea at the Black Lion Hotel the party left for Whitby by the 6.22 train due at 6.49. After dinner the members all assembled at the Crown Hotel, and the usual votes of thanks were passed to those who had contributed to the success of the excursion.

SATURDAY, JULY 28TH. — The members journeyed to Skinningrove as before, except that this time there was no breakdown in the tunnel. Having arrived at the shore the party walked westwards round Huntcliff to Saltburn. The geology of Huntcliff is very much the same as that of Boulby, except that the highest beds exposed in the cliff are the *Spinatus*-zone. As at Boulby, the *Jamesoni* beds rise from the shore and form the base of the cliff, and come down again before Saltburn is reached. There is the same line of *Am. fimbriatus* nodules marking the base of the *Capricornus*-zone. From the point there is a fine view to the west of the long stretch of sands and low glacial cliffs which extend from Saltburn past Redcar to the mouth of the Tees, some five or six miles, and of the Durham coast beyond. The Director mentioned that a raised beach had been described at Saltburn, but he thought that, in view of its occurrence on the slopes of the glacial cliffs and the absence of such beaches on other parts of the Yorkshire Coast, the question of its true age and origin required further investigation. From Saltburn the members proceeded by the 2.20 train to Redcar, arriving at 2.33. Here they found the *Bucklandi* and *Angulatus* scars, which are uncovered at low water, fairly well exposed, and in the former some very large water-worn ammonites were seen which are probably the zonal ammonite, or one of its near allies. *Am. angulatus* was also found, and the well known *Pleurotomaria anglica*, *Gryphæa arcuata*, *Cardinia Listeri*, and other characteristic fossils.

The Director mentioned that these *Angulatus* beds were the lowest exposed on the Yorkshire Coast. They formed the centre of an anticline, the *Bucklandi* beds being again occasionally exposed farther east. To the west he pointed out the Coatham scars, which jut out in a reef, and consist of beds from the *Margaritatus*-zone down to the *Jamesoni*, with a dip to the north-west. The members obtained tea at Redcar, and returned to Whitby by the 4.58 train, arriving at 6.49.

The excursion proper then came to an end, the party having walked in the six days the whole length of coast from Blea Wyke to Saltburn, a distance of about 28 miles, with the exception of the three mile stretch from Whitby to Sandsend (which several of the members traversed unofficially), and the piece from Runswick round Old Nab to Staithes, also about three miles.

As several of the party were going on to the British Association Meeting at York on August 1st, and as others evinced a desire to prolong their stay at Whitby, the Director undertook to conduct two more excursions, this time going inland, partly for the sake of variety, and partly because the exigencies of the tide made it desirable.

MONDAY, JULY 30TH.—Those members who remained, numbering about 15, left the town station by the 9.10 train for Levisham, arriving at 9.59. The railway follows the valley of the Esk as far as Grosmont, and then, leaving the main stream, it follows the Murk Esk and its tributary, the Eller Beck. About half-way between Goathland and Levisham it crosses the watershed at a place called Fen Bogs, and follows the Pickering Beck down the beautiful gorge of Newtondale, which debouches into the broad Vale of Pickering at that town. The section of railway from Goathland to Pickering is one of the most picturesque in England. Though the watershed is crossed, the railway runs all the time in a steep-sided valley, which is in origin a true gorge, having been largely formed, if Professor Kendall be right, by the pouring out of the waters, which had been held up by ice and moraines in the Upper Esk, through the handiest channel into the great lake which then filled the Vale of Pickering. On arriving at Levisham the Director led the way up on to the platform of Kelloway Rock, which forms a sort of level terrace on each side of the valley, the bottom of which is formed of Upper Estuarine Beds. About a mile and a half from the station the party stopped at the view tower known as Skelton Tower, situated about 150 feet above the railway at a bend of the valley, from which a splendid view up and down Newtondale was obtained. The slope down to the railway is very steep and well wooded; the slope up from the terrace on which the tower stands is more gentle, and consists of bare moor covered with heather. This slope is Oxford Clay with Lower Calcareous Grit at the top. Just below the tower a few members followed the Director down the somewhat precipitous slope to examine the Cornbrash which crops out some 15 ft. below. This is an irregular limestone band about 3 ft. thick, and very full of fossils. *Ammonites macrocephalus*, *Echinobrissus scutatus*, and several other species were obtained. The Kelloway Rock Quarry, a little way farther on, was then visited, and the party were lucky in finding a specimen of one of the starfishes peculiar to Newtondale, either *Astropecten orion*, or *A. claviformis.* These, as is well known from specimens in museums, always occur as hollow casts in the sandstone. A walk of two miles led to Saltersgate Inn, just off the main valley, where welcome rest and refreshment were found, the day being very hot. Retracing their steps, the members climbed the hill of Lower Calcareous Grit, and looked down into the curious inlier of Kelloway Rock known as the Hole of Horcum. From the top of the hill a fine view was obtained, to the south, of the Wolds and Howardian Hills on the other side of the Vale of Pickering. The party descended into the Hole and followed the Levisham beck down till it passed off the Kelloway Rock and Oxford Clay on to the Lower Calcareous Grit, when they left the valley and struck off across the fields, composed of the overlying Lower Limestones, to Levisham village. Between here and the station a quarry was passed in the Lower Limestone, and some fossils were found, though they were difficult to extract from the matrix. The return was made from Levisham by the 5.14 train reaching Whitby at 6.5.

TUESDAY, JULY 31ST.—The day broke with a tremendous thunderstorm, which fortunately cleared off before the time for starting, which was 10.10 from the town station, the destination being Egton Bridge, which was reached at 10.35. The party first examined a very good section of the Cleveland Dyke, which here crosses the Esk. On the north side of the river it is worked for road metal, and on either side of the dyke may be seen the well-baked Lias shales, which were recognised from the presence of *Inoceramus dubius* to be of the zone of *Am. serpentinus.* The party then walked up the course of the river through the beautiful Arnecliff woods to Glaisdale End at the mouth, like a bottle-neck, of the singularly beautiful Glaisdale. This is an extremely fertile little valley about four miles long, well filled with boulder clay, which accounts for the excellence of the soil. The sides are of Upper Lias, with Lower Estuarine beds and Dogger above. At Postgate Hill the Dogger was formerly worked for ironstone, and the old tips of stone brought out of the mine still remain. This is a well-known locality for Dogger fossils, and the members spent a long time here breaking up the blocks and filling their bags with the fossils. Most of these are in the form of casts, but the shell is in several cases preserved, and the ornamentation of the shells is always beautifully shown in the external casts. After tea in a neighbouring cottage the party returned to Glaisdale station, where the picturesque "Beggars' Bridge," over the Esk was duly admired, and returned to Whitby by the 6.7 train, arriving at 6.35, and so the excursion ended, which, if marked by nothing else, was notable for the splendid weather, which was uniformly fine but for the two thunderstorms mentioned, and neither of these interfered with the outdoor work.

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EXCURSION TO THE RAYLEIGH HILLS, ESSEX. (HADLEIGH, THUNDERSLEY, AND DAWES HEATH).

SATURDAY, SEPTEMBER 15TH, 1906.

Director: A. E. SALTER, D.SC., F.G.S.

Excursion Secretary: T. W. READER.

Report by THE DIRECTOR.

THE party, which numbered about thirty and included several members of the Essex Field Club, left Fenchurch Street at 2.6 p.m., and on arriving at Leigh-on-Sea ascended the steep slope which leads to Leigh Church, and after some difficulty obtained conveyances to Thundersley.

The first section visited was situated a little east of the Reservoirs, where 5 ft. or 6 ft. of gravel resting on sand was exposed at about 250 ft. O.D.

The Director pointed out that the Rayleigh Hills, upon one of the highest parts of which they were then standing, were formed of London Clay, which was overlaid by Bagshot Sands. Above these, patches of gravel similar to that now before them occurred, and these by preserving the subjacent strata from the action of denuding agencies had preserved them, while all around had been denuded away. The Director then drew attention to the composition of the gravel, which in addition to débris from Tertiary strata, *e.g.*, sarsens, flint pebbles, etc., contained a considerable amount of Lower Greensand Chert from the Wealden Area to the south of the Thames. Some of the gravel had been consolidated into a hard ferruginous conglomerate. If the hypothesis that these outlying patches of gravel were formed by former streams from the Wealden Area were correct, it showed that since the gravels were deposited the lower part of the Thames Valley, as we know it, had been initiated.

In comparing this deposit with that seen at Beggar Hill earlier in the year[*] it was pointed out that the Bunter débris and Igneous rocks present at the latter were absent in the former. Also nothing derived from Jurassic strata or Basalt was observed at either of them.

The Director also remarked that Eoliths were likely to occur here, and that he had obtained one which had satisfied Mr. A. S. Kennard, F.G.S., who also expressed the opinion that the gravel was a likely one for their occurrence.

The remarkably fine view from this point was greatly admired, the Laindon Hills standing out well to the east.

A few days before the excursion some Essex papers stated that discoveries of flint implements had been made at Thundersley, and also that a band of marine shells had been found there. Some members investigated these reports, and found that a few well-worked neolithic flakes had been found by Mr. Mabey in his garden, and the Director was able subsequently to examine the "marine shells," which proved to be ferruginous concretions from the Bagshot strata.

Proceeding to Dawes Heath the party were shown a section in what is known as the Bramble Hill Pit, which from the Director had recently obtained a fair-sized boulder of green Oldbury Chert. The gravel was similar to that already seen, and rested on Bagshot Sand.

Another section close by was visited, and then a sharp walk

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[*] *Proc. Geol. Assoc.*, vol xix, p. 317.

through the woods brought the party to the Crown at Hadleigh, where tea was obtained.

Some few members found time to examine Hadleigh Church, into the wall of which a large sarsen has been built, and to visit the ruins of Hadleigh Castle.

In replying to the vote of thanks proposed by the President the Director stated that he hoped, in spite of the unfortunate delay, he had been able to bring out the following points:

1. That the Rayleigh Hills owe their existence as such to the occurrence of porous gravel and sandy patches which have resisted denudation.
2. That the presence of Lower Greensand Chert in the gravels points to former fluviatile connection with the Wealden Area.
3. That large boulders (sarsens) occur in these gravels at 250 ft. O.D., which are rarely if ever found in the much more extensive gravels at lower levels (70 ft.—80 ft. O.D.), *e.g.*, at Southend (in Southchurch Road) and at Westcliff, etc.
4. That flints showing Eolithic chipping, similar to those on the Plateau south of the Thames, probably occur on the Rayleigh Hills in beds of stratified gravel.

The party returned to London by the 7.20 p.m. train.

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NOTE.—The enclosure of a page-number in square brackets signifies that upon that page the paper or lecture is not printed IN EXTENSO, *but is merely announced or otherwise referred to.*

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